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DEPARTMENT OF THE ARMY FIELD MANUAL

Co A, 1st Bn, 137th Inf FIELD RADIO RELAY TECHNIQUES

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FIELD RADIO RELAY TECHNIQUES

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COMMUNICATING

CHAPTER 1

INTRODUCTION

Section 1. GENERAL

1. Purpose and Scope

The purpose of this manual is to provide tactical and certain technical information for staff planners and those technicians within the field army concerned with the installation and operation of radio relay systems. The tactical employment of radio relay equipment together with its applications and use with wire facilities to attain an integrated communication system is included. General information is given on the application of radio relay, system planning, radio-wave propagation, siting and installation, frequency selection, noise and interference suppression (antijamming), field expedients, system maintenance, and related subjects.

2. References

Publications, training films, and other references pertaining to the subject within the scope of the manual are listed in appendix I.

Section II. RADIO RELAY SYSTEMS

3. General

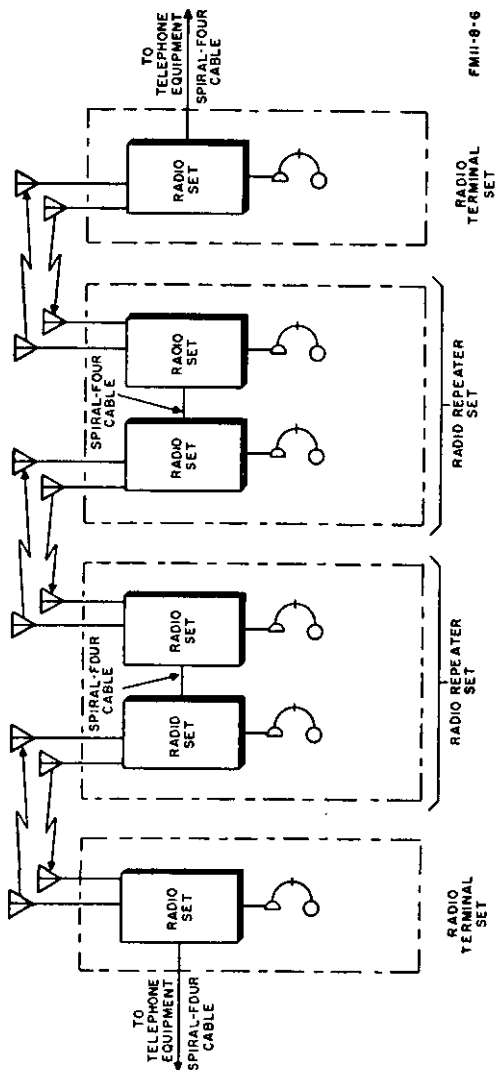
a. A radio relay system consists of a series of radio stations operating in tandem on frequencies above 30 megacycles (mc). When used in conjunction with carrier or other multiplexing equipment, a radio relay system provides communication channels for telephone, teletypewriter, and facsimile. When wide-band equipments are used, channels suitable for electronic data and television transmission also may be realized.

b. Every radio relay system has two terminals—one at each end of the system. Radio terminal sets often are installed as part of, or adjacent to, the carrier terminal. The maximum distance between radio terminal sets (without intermediate radio relay sets) is governed by the type of equipment used.

c. Radio repeater sets are installed where necessary to retransmit the signals from the preceding terminal or radio repeater. These stations generally are isolated from other communication installations. The block diagram of a typical radio relay system is shown in figure 1.

4. Use of Radio Relay Systems

a. Radio relay systems may be used as a primary communication facility, or used to supplement and complement an existing cable and open-wire carrier system. Specifically, radio relay systems may be—



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Figure 1. Typical radio relay system, block diagram.

- (1) Used tactically to establish initial trunk line communications in a rapidly moving situation and later supplemented by wire if the situation permits.
- (2) Used as a single-channel radio circuit.
- (3) Used as a multiple-channel primary facility; the number of channels will depend on the type of equipment used.
- (4) Used as a multiple-channel system to supplement a wire system or to extend a wire system.
- (5) Used as an integral link in a wire system.
- (6) Used in combination with multiplexing equipment to provide a combination of telephone, telegraph, facsimile, and (with certain equipments) television or telemetering data transmission over a single radio path.
- (7) Used in lieu of wire for long lines trunk service.

b. Radio relay systems have the following advantages:

- (1) They provide command control (talk-like-a-telephone) communications.
- (2) They enable communication over relatively long distances.
- (3) Installation time is much less than that required for wire trunks.
- (4) They are highly adaptable to wide-front, fast-moving tactical situations. Once antennas are erected and oriented and connections made to end equipments,

the system is ready for preliminary adjustment (system lineup) and operation.

- (5) Where wire installation is impractical, communication can be rapidly established over otherwise impossible terrain.
- (6) They are less susceptible to direct enemy action and sabotage.
- (7) Maintenance man-hours are greatly reduced (when compared to the maintenance of long wire trunks).

c. Radio relay systems have the following disadvantages:

- (1) Radio terminal and radio repeater stations are frequently installed in locations, such as hilltops and other hard-to-reach places, where logistical support frequently is difficult.
- (2) Radio relay circuits are susceptible to enemy interception and direction-finding activities.
- (3) Communication may be disrupted or seriously impaired by enemy jamming.
- (4) Lack of sufficient frequency channels may restrict the number and length of systems that may be installed.
- (5) Antennas frequently must be elevated above surrounding cover, thus possibly making station locations known to the enemy or to enemy agents.

CHAPTER 2

EMPLOYMENT OF RADIO RELAY SYSTEMS

Section I. TACTICAL APPLICATIONS

5. General

Because of the inherent versatility and flexibility of radio relay equipment, there can be no set rules or yardsticks laid down for a stereotyped application of such systems to tactical communications. In each instance, the amount of radio relay equipment to be used will be dictated by the *Signal Plan* which, in turn, results from the estimate of the signal situation made by the signal planner.

6. Specific Considerations

a. Radio relay circuits always are operated point-to-point; that is, from terminal to terminal or, if radio repeaters are used, from terminal through the repeaters to terminal.

b. Normally, the superior headquarters will provide the entire radio relay system, including the terminal equipment at the subordinate headquarters plus necessary repeaters. Signal plans

must provide for radio terminal sets to be attached to subordinate units, particularly when such units are not authorized terminals organically. Attached terminal teams remain under the command of their parent organization and are employed by the higher headquarters concerned.

c. Communication planners also must consider—

- (1) The type and quantity of radio relay equipment available.
- (2) The characteristics and proposed possible uses of the equipments. (General overall applications are given in ch 1. Equipment characteristics are listed in this ch and in app II.)
- (3) The usability of assigned operating frequencies.
- (4) The advantages and disadvantages of radio relay as compared with wire communication facilities (par. 4).
- (5) Capabilities of existing and proposed wire systems.
- (6) Integration of the radio relay system with the wire system.
- (7) Where communications systems are adjacent or intersect, repeater stations may be consolidated. This will simplify logistical support and security requirements and will reduce the number of personnel.
- (8) The possibility of air-transporting radio

relay equipment to provide communications for special situations such as area damage control following an atomic strike.

- (9) The possibility of using radio relay as a keying-line facility for remote operation of radio teletypewriter circuits, or remote operation of high-frequency (hf) radio transmitters.

d. Specific information for use in computing and selecting radio relay paths and sites is covered in chapter 3. Frequency selection and methods for determining operating frequencies are in chapter 4.

7. System Procedures

Reliable radio relay operations can best be realized when based upon standing operating procedures (SOP). An SOP must be clear, detailed, and should include as a minimum, but not be limited to, the following:

a. Pre-operation.

- (1) Signal operations instruction (SOI) extracts of the prearranged message code, the map-coordinate code, and the unit authentication system will be issued to the team chief. Arrangements must be made in advance to insure timely delivery of new extracts as required.
- (2) Each radio relay team chief will be issued tactical maps covering the probable area in which the team will operate.

b. Tactical Employment. During operations

any orders for tactical employment must be given in code, using the SOI extracts. The team chief who receives the message must authenticate the transmission. Conversely, the person originating the instructions also should be required to authenticate.

c. Clear-Text Information. Transmission of the following types of clear-text information over order-wire circuits (engineering channels) must be prohibited:

- (1) Radio relay station locations.
- (2) Movement instructions to stations.
- (3) Identification of stations with units.
- (4) Instructions regarding future tactical deployment.

d. Changes in Circuitry. Information regarding changes in a circuit must be transmitted in both directions—from higher to lower headquarters and vice versa. Orders regarding the system will come from the terminal servicing the higher headquarters.

e. Equipment Considerations.

- (1) Circuits must operate exactly on assigned frequencies.
- (2) Correct antennas must be used.
- (3) Transmitting and receiving antennas must be oriented properly. When two or more systems utilize the same site, all receiving antennas should be in one group and all transmitting antennas in another group. Each of the groups should be physically separated by the recommended distance.

- (4) Proper system lineup procedures must be followed in accordance with instructions outlined in equipment technical manuals or other official instructions.
- (5) No changes in frequencies, except within prescribed limits, should be made without approval of the frequency allocation authority.

8. System Flexibility

a. General. Radio relay systems are extremely flexible and furnish a variety of communication capabilities. These systems may be used in the following ways:

- (1) To extend the lines of communication in a fast-moving situation, mobile equipments may be employed in jumpteam operation. These teams can displace to forward, rear, or lateral locations prior to the actual displacement of headquarters, thus insuring continuous communications. By maintaining communications at the original command post (CP) with duplicate radio relay equipment or with wire systems, the circuits may be passed to the new CP when the command passes.
- (2) A radio relay system may be inserted into a wire system without reducing wire capabilities. Where terrain such as large bodies of water or deep and rugged valleys make wire construction

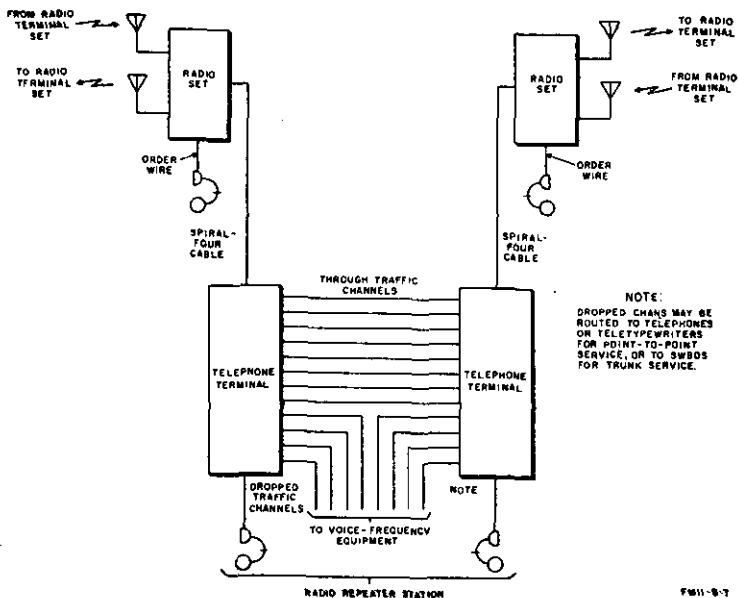


Figure 2. Dropping channels at radio relay point, block diagram.

impractical or impossible, radio relay will be installed.

- (3) Many radio relay equipments are adapted so that channels may be dropped at relay points along the axis of communication. These facilities may be used to provide lateral circuits, to service local headquarters, etc (fig. 2). Radio relay equipment of older type also can

be so adapted, if additional carrier equipment is provided.

- (4) Through proper arrangement of terminal equipments, channels may be re-routed without termination over forward or lateral area systems. This procedure is known as *strapping-through* and provides point-to-point circuits over systems normally used for trunk service.

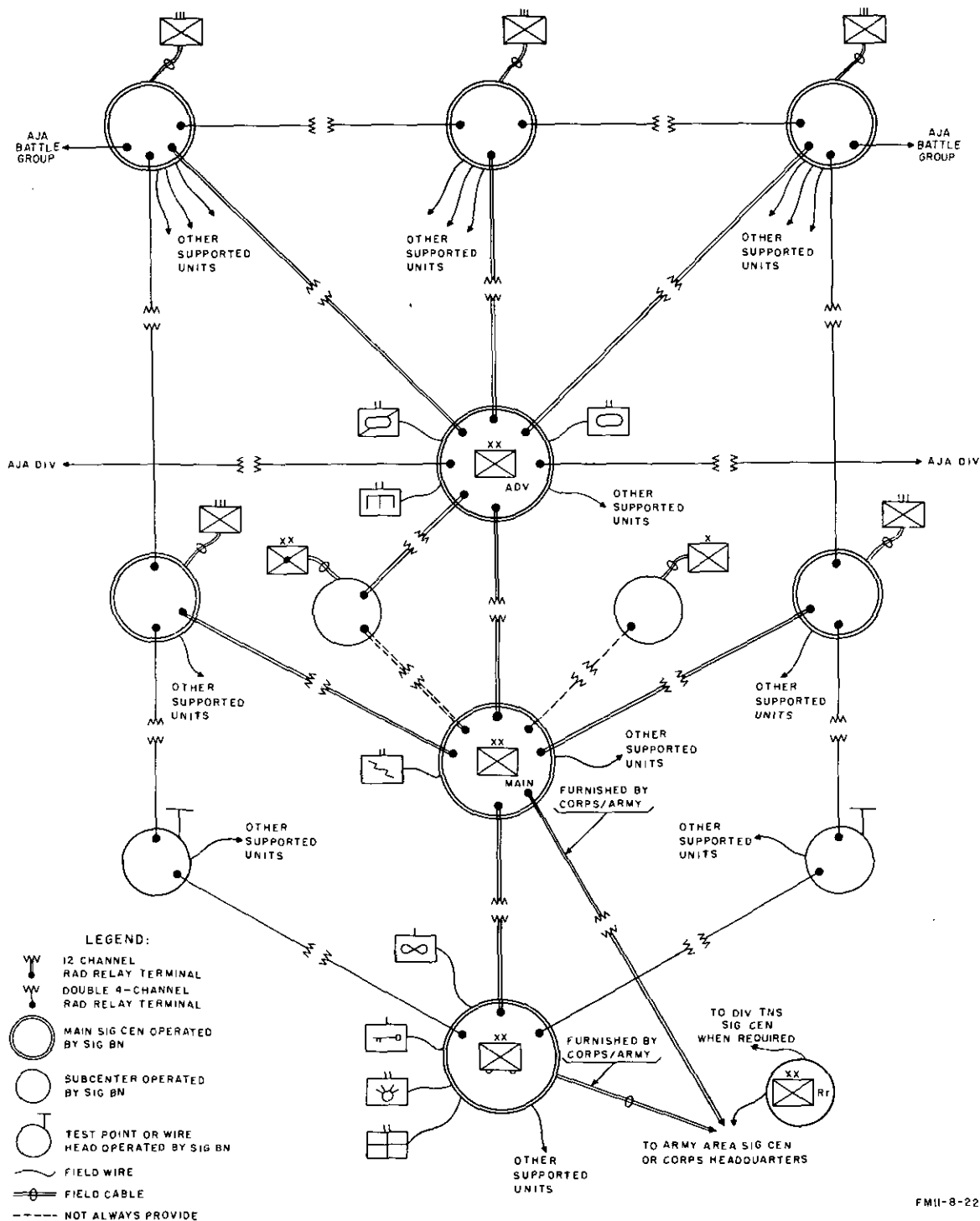
b. Adaptation of Equipment. Radio repeater sets may be arranged to function as two *terminal* stations. This adaptation may be used when there is not sufficient terminal equipment available to provide circuit requirements. When used in this manner, however, additional carrier and ringing equipment is required.

Section II. TYPICAL USE IN AREA-TYPE WIDE-FRONT SITUATIONS

9. General

In all cases, the communication requirements determine the number and type of circuits needed for interconnecting units or area communication subcenters. The estimate of the signal situation and the resulting signal plan should indicate the application and scope of the radio relay system.

a. After determining system requirements, a detailed terrain analysis, with particular empha-



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Figure 3. Division-type radio relay system.

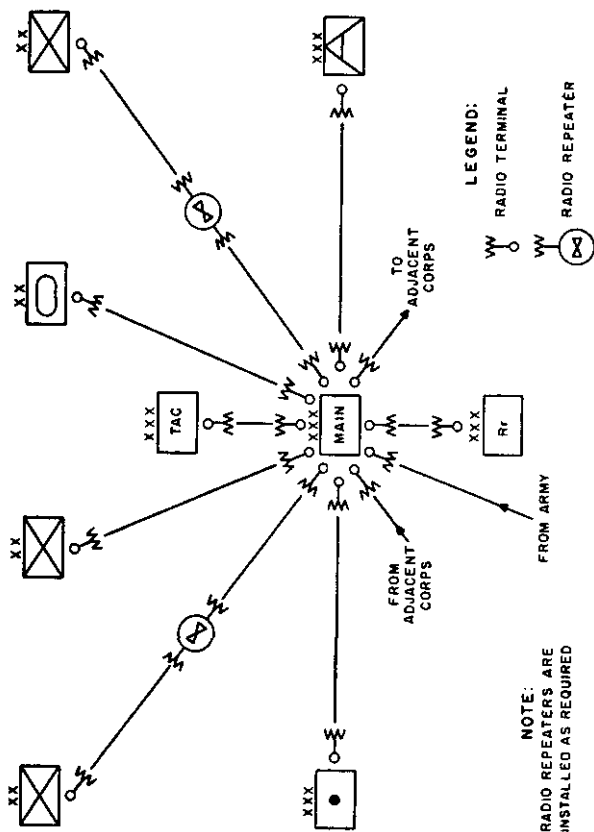


Figure 4. Corps-type radio relay system.

minals, will indicate the number of radio repeater sets required for each circuit. Whenever possible, physical type relief maps should be used in planning terminal and relay sites. Line-of-sight paths over reasonable distances will eliminate requirements for radio repeater sets.

b. Equipment transmission yardsticks are covered in the technical manuals accompanying the equipments.

10. Tactical Applications

Figures 3 through 5 indicate typical applications of radio relay systems at division, corps, and field army levels. Due to the flexibility and versatility of radio relay equipment, it must be clearly understood that these are but a *few* of the possible applications for these systems. The actual number of applications is limited only by the ingenuity and initiative of the signal or communication planner and equipment capabilities.

a. Figure 3 shows a division type radio relay system in conformance with latest divisional concepts.

b. Figure 4 shows one application for a corps tactical system.

c. Figure 5 shows a typical field-army 12-channel radio relay system. The number of area communication subcenters varies in accordance with the communication requirements.

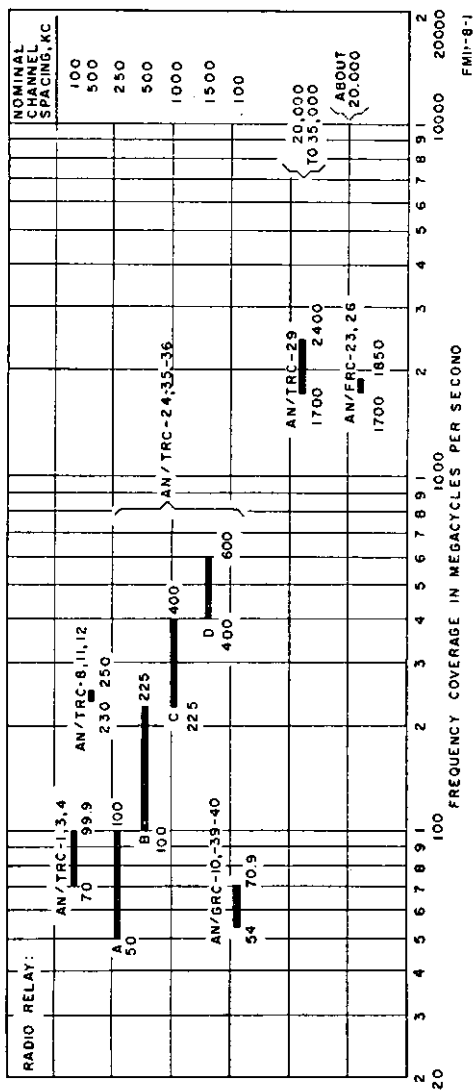


Figure 6. Frequency chart for radio relay sets.

Section III. EQUIPMENT CAPABILITIES AND LIMITATIONS

11. Methods of Operation

Certain radio relay equipments may be used without multiplex equipment to provide a single voice channel over the radio path. Such single-channel 1-hop systems may be operated in one of three methods.

a. One-way operation without a break-in feature, referred to as *simplex* operation, requires only one radio frequency.

b. One-way operation with a break-in feature, referred to as *half-duplex* operation, requires two frequencies. Both simplex and half-duplex operation involve push-to-talk operation at the terminals.

c. Simultaneous 2-way transmission, called *full-duplex* or *duplex* operation, requires two radio frequencies. This method does not involve push-to-talk operation.

12. Operating Frequencies

Operating frequencies for radio relay equipment vary according to type and are shown in the chart, figure 6. Additional characteristics for radio relay equipment are covered in appendix II.

CHAPTER 3

SYSTEM PLANNING

Section I. GENERAL

13. System Planning

a. System planning includes the overall layout of radio relay circuits, locations of sites, choice of equipment, and frequency allocation and assignment.

b. The factors to be considered in planning radio relay systems are—

- (1) Circuit requirements as determined by tariff studies and/or previous experience.
- (2) Capabilities of the radio relay equipment in conjunction with the associated multiplexing terminals.
- (3) Propagation characteristics and terrain features over which the radio system will operate.
- (4) Siting of radio sets and antennas.
- (5) Power-balance calculations such as required inputs, noise levels, and power outputs.
- (6) Interference reduction by frequency selection.

- (7) Advantages gained by using cross-polarization, separate masts, and antenna directivity.
- (8) Field methods of minimizing interference.
- (9) Limitations of spiral-four cable in a radio system.
- (10) Availability of frequencies for assignment.

c. A *radio relay system* consists of two radio relay terminals and as many radio repeaters as are required (consistent with the technical capabilities of the equipment) to span the distance between the two terminals. A *hop* is the terrain distance separating a radio transmitter from the receiver that receives its transmission. A *path* is that part of the atmosphere through which the radiated wave passes. A *direct path* is one that has no intervening obstacles and is said to be a line-of-sight. An *indirect path* is any path other than a direct path between two stations (par. 96).

14. System Considerations

a. A radio relay system may be used directly for primary trunks, or as a link in an existing wire system. The installation may be temporary or permanent. With some types of radio relay equipment, channels may be dropped between terminals and made available at some intermediate point (fig. 2).

b. The permissible number of hops depends on the type of equipment. Distortion, noise, and the possibility of circuit failure due to inoperative

equipment increase as the number of hops increases.

15. Multiplexing Equipment Connections

a. Terminal Connections. Through the use of multiplexing equipment, channels may be brought out as either 2-wire or 4-wire circuits. These circuits are connected in the normal way to signaling equipment and switchboards or to carrier telegraph equipments.

b. Through Connections. Where systems are to be extended, through-connections between multiplexing equipment are made on a 4-wire basis. The standard signal levels specified in the equipment technical manual should be retained.

c. Baseband Connections. In interconnecting radio relay and wire carrier systems, the baseband connection must be made on a 4-wire basis. Baseband connections between certain equipments may require limited lengths of coaxial, spiral-four, or other special cable. Baseband connections, as well as the required signal levels, are covered in appropriate equipment manuals (app I).

16. Separation of Radio Terminal from Carrier and Multiplex Equipment

a. At the terminal installations of systems using wire carrier (such as the CF-1 or the AN/TCC-3), carrier equipment may be located with the radio terminal equipment or centralized near the telephone switching central.

b. At division and lower levels, carrier equipment usually is *married* to the radio equipment in the same vehicle. Such arrangement maintains the tactical identity of the radio carrier terminal, and reduces emplacement and *tear-down* time. It requires construction of a greater number of wire lines, however, between the AN/TRC carrier terminal and the telephone switchboard.

c. At higher echelons (corps and above), carrier equipment frequently is centralized near the telephone switching central. This permits greater flexibility of employment for the available carrier equipment, and reduces the number of wire lines required. In such installations, spiral-four or other suitable broad-band wire facility is used to feed the radio terminal output to the carriers, but the wire lines to the switchboard are greatly reduced in length.

d. For systems using their own multiplex (extremely wide-band) units, the multiplex set must beat the radio terminal. The 4-kilocycle (kc) carrier channels can be extended from the radio terminal to the telephone switching center by 2-wire system, 4-wire system, or by wire carrier with terminals at these two points.

e. If the radio terminal is separated from the switching center as outlined above, a voice-frequency engineer channel between the two locations will be required for efficient maintenance of the system.

Section II. WAVE PROPAGATION

17. General

a. The radio frequencies from 30 to 300 mc represent the very high frequency (vhf) range and the frequencies from 300 to 3,000 mc, the ultra-high frequency (uhf) range. The properties and phenomena associated with radio waves in the vhf band and the *lower* part of the uhf band are similar; therefore, when used in this manual, the term *vhf* will refer to this range of frequencies.

b. Radio propagation in the vhf range is confined to ground waves—waves that travel near the earth's surface. Sky-wave transmission, by means of reflections from the ionosphere, will sometimes occur in the vhf band—particularly at frequencies between 50 and 100 mc. Studies on scatter propagation using the ionosphere and troposphere as a reflecting medium for vhf and uhf are presently being conducted and show possibilities of a signal *radiating* several hundred miles. Because ground waves attenuate rapidly with distance, useful transmission in the vhf band between radio sets generally is limited to relatively short distances (25–35 miles), unless exceptionally good antenna sites on high hills are available at both ends of the path. An exception to this rule sometimes occurs where high obstacles are located at the approximate center of a transmission path (par. 19c).

c. The distance, range, and performance estimates given in technical manuals generally are

based on standard propagation. Recent experience in oversea theaters indicates that meteorological conditions, such as temperature and humidity of the troposphere (par. 18), sometimes give rise to what is termed *guided propagation*. *This phenomenon may greatly extend the distance over which usable field intensities are received.* Such conditions are most frequently found where radio sets are located near the shore of an ocean or other large body of water and may be present for either long or short periods of time.

18. Wave Propagation Phenomena

a. *General.* The path of travel for radio waves in the vhf range is the troposphere. *The troposphere is the layer of atmosphere directly adjacent to the earth's surface.* It extends upward approximately 6 miles. The temperature normally decreases about 10° centigrade (C.) per mile, with increasing altitude; the temperature at the upper boundary is about -50° C. Above the troposphere is the stratosphere, in which the temperature remains relatively constant at approximately -50° C. Because of changes in moisture content and temperature at the troposphere, certain wave propagation phenomena, such as *reflection* and *refraction* occur.

b. *Refraction.* Propagation of radio waves in the troposphere is materially influenced by the distributions of temperature, pressure, and water vapor. The variation of these qualities with height decreases linearly in a standard atmosphere. (The condition most nearly approximated

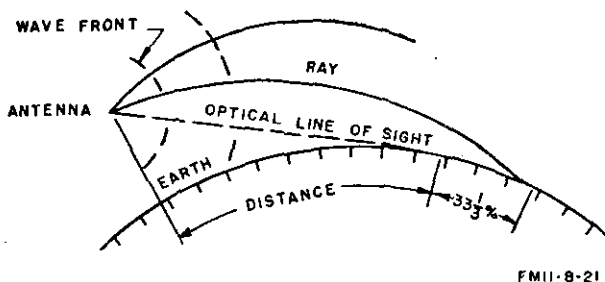
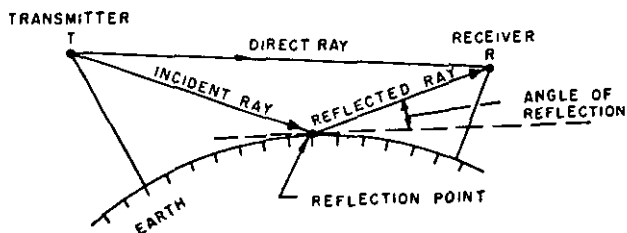


Figure 7. Refraction.

in the temperate zone has been accepted as the standard atmosphere.) Radio energy emitted from a transmitter antenna may be represented by a series of concentric spherical wave fronts or radial lines called *rays* (fig. 7). Since the refraction index normally decreases with height, the upper portions of these wave fronts move with higher velocities than the lower portions, and consequently the wave path may be represented by rays curved slightly downward toward the earth. As a result, under average conditions, the distance to the radio horizon is $33\frac{1}{3}$ percent greater than the optical line-of-sight distance. This curvature of the rays by the atmosphere is called *refraction*.

c. *Reflection.* Over line-of-sight path, TR (fig. 8), the radio wave at receiver R is the vector sum of the radiations arriving by way of both the direct and reflected ray paths. The intensity of the reflected ray path depends primarily on how effective the earth or sea acts as a reflecting body.



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Figure 8. Reflection.

Over water and salt flats, for instance, the reflection is essentially 100 percent. Over land areas with gentle rolling country and some vegetation, the reflection is approximately 10 percent. The phase lag of the reflected wave with respect to the incident wave at the point of reflection is, for all practical purposes, 180° . Although the angle of reflection is small, the distance traveled by the incident and reflected ray is greater than that of the direct ray.

d. Diffraction. The mechanism by which radio waves curve around edges and penetrate into the shadow region behind an opaque obstacle is called diffraction. This effect is important because it allows a limited extension of the line-of-sight path length (fig. 9). This extension of the line-of-sight path is indicated by the distance TR—the hop length.

e. Results of Wave Propagation Phenomena. As the receiving antenna is raised above ground level, the received signal strength rapidly increases because of decreasing diffraction until

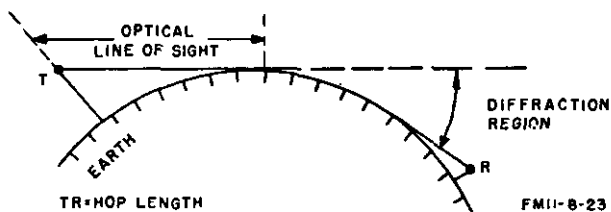


Figure 9. Diffraction.

the grazing point is reached (fig. 10). Above this point the direct and reflected waves interfere with each other and result in maximum and minimum Fresnel patterns. The first maximum occurs when the difference in path length between the direct and reflected wave is one-half wave length because the reflected signal undergoes a 180° phase reversal at the reflecting point. The succeeding maximums are odd multiples of one-half wave lengths. The magnitudes of the maximum and minimum fields depend on the amount of reflection by the surface. If the transmission path is clear—that is, without intervening obstacles—an increase of 6 db in received signal strength will be obtained by doubling the height of one antenna, or 12 db if both antenna heights are doubled. This phenomenon holds true only for a distance of about 40 miles, or within the limits of the radio horizon.

19. Propagation in Vhf Band

a. Over Smooth Earth or Water.

- (1) Under the ideal condition of smooth earth, the intensity of the transmitted

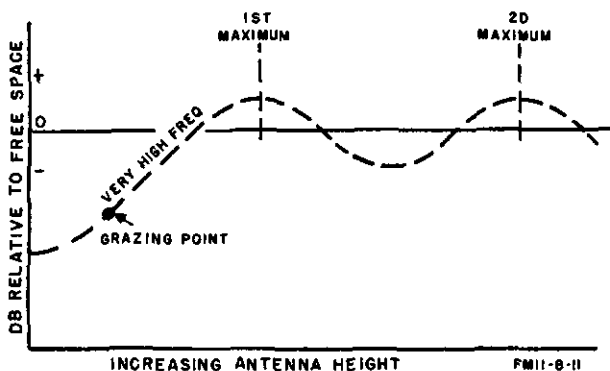


Figure 10. Results of wave propagation phenomena.

signal beyond the first mile or so decreases with distance. Similar results are obtained over water because the surface is smooth enough to approach the ideal.

- (2) Figure 11 shows the theoretical relationship between transmission loss in decibels (db) and distance over smooth land. The frequencies used in this case are 50 and 300 mc, with antenna heights of 45 feet. The field intensities obtained in practice will be less than those shown, because of irregularities in terrain, the presence of trees, and other factors that cause the actual conditions to differ from the theoretical. With allowance for these factors, it is possible to calculate the distance range to be expected.

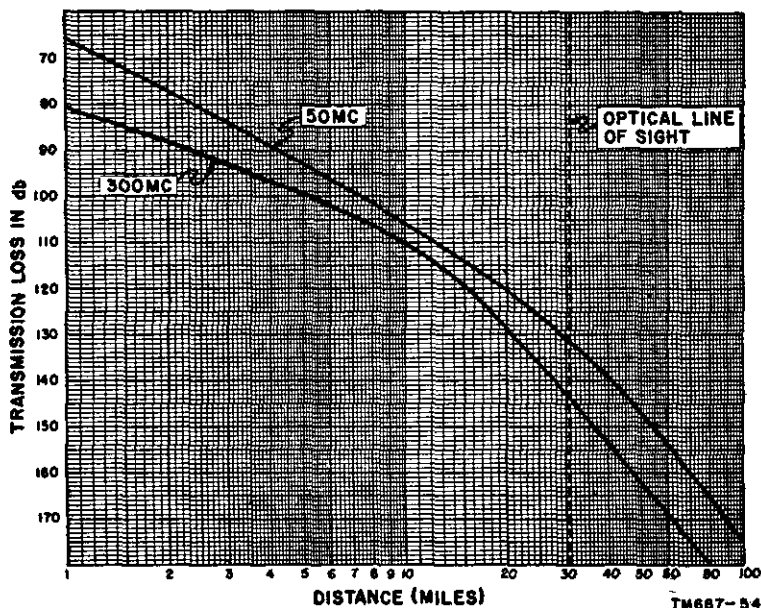


Figure 11. Graph of db loss versus distance over smooth earth.

b. Over Irregular Terrain.

- (1) Propagation characteristics over irregular terrain are quite different from those from smooth earth or sea water. In this case, the variation of db loss with distance depends largely on the profile of the terrain between transmitting and receiving antennas. An increase in distance may result in either decreased or increased db loss, depending on the

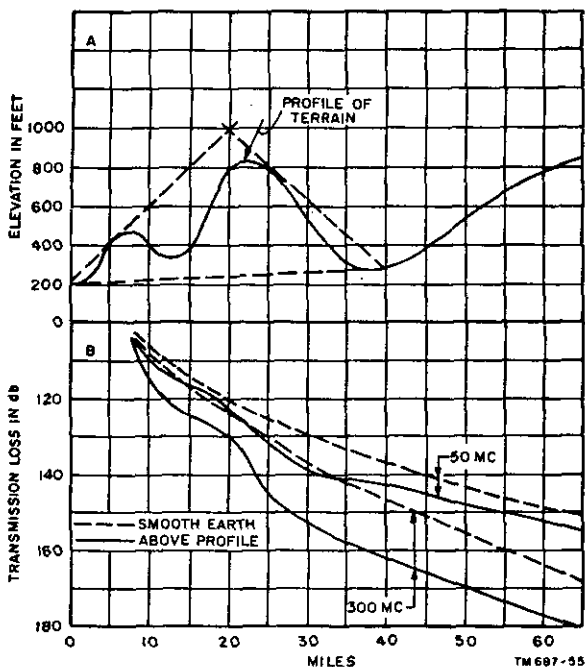


Figure 12. Path profile and associated loss versus distance.

topography involved. Substantial changes in db loss may result from re-locating stations, even without any change in the distance between them.

- (2) A profile for an assumed transmission path over hills with typical values of db loss likely to be encountered at various points along the path is shown in figure 12. Two facts with regard to trans-

mission in hilly country are emphasized: first, *the choice of antenna site is very important*; and, second, *there is no satisfactory basis for calculating general distance ranges*. Instead, the db loss may be *estimated* for a given site involving a path of known profile, and thus the selection of antenna sites may be based on the db loss estimated for various available locations.

c. *Over Very High Obstacles*. Recent experiments have indicated considerable gains in received signal strength above that obtained over smooth earth may be expected from *diffraction* over an obstacle located in the transmission path. In quite a number of instances, transmission paths containing a very high obstacle have been spanned with excellent results for distances over 150 miles. Experiments also have shown that for the best use of this diffraction phenomenon, the obstacle should be equivalent to a knife edge, and be situated in the approximate center of the transmission path. To prevent excessive attenuation radio repeater or terminal sets should be placed as far from the obstacle as possible.

Section III. SITING TECHNIQUES

20. General

Siting is the practical application of radio relay theory. Many factors must be taken into account in order to lay out a radio relay system. It is

possible to set up a radio relay system by installing radio repeater sets on hills selected at random, without regard to any of the factors mentioned in section IV. Such a system *might* operate, but the chances of satisfactory and efficient operation would be very small. This section covers some of the *general* considerations involved in siting, and a more detailed study is given in section IV.

a. In addition to other considerations, physical security must also be considered as a factor in the selection of a radio repeater site—this is particularly true in isolated areas. A guide for organizing a perimeter defense is given in appendix III.

b. In engineering a radio relay system, especially where continuous operation is essential, considerable attention must be given to the location of radio repeater station, particularly in rolling terrain, or in areas where scatter or reflection may introduce problems.

c. Radio repeater sites usually follow a zigzag course. One reason for this pattern is that the terrain seldom lends itself to a straight line of radio repeaters without having some of the hops unnecessarily short and others too long for satisfactory reception. Also, hills rarely are spaced so that the repeaters are in a straight line, and still have adequate elevations. However, there are exceptions to every rule and zigzagging is not always necessary. It is possible and practical to site the repeaters in a straight line and still have reliable reception. Alternate polarization of

antennas, and/or alternate frequencies may be used to give satisfactory reception.

d. Siting may be done by a number of methods or by a *combination* of separate methods. Contour maps, aerial photographs, and surveys may be used satisfactorily. Usually, sites are chosen *tentatively* from contour maps, and a field trip or aerial survey made to verify the choice.

21. Remote Operation

Terminal stations usually are located fairly near the headquarters they serve. However, if such headquarters are located in a valley, or behind a terrain obstacle, remote operation of the radio terminal may be required. In such instances, a wire link to the radio station is installed.

22. Field Inspection

a. The initial contour map reconnaissance to select terminal and repeater sites should provide several alternate locations for each proposed installation. Some of the alternate sites will be discarded on the basis of profiling, and the balance must be checked by actual on-the-ground inspection.

b. A field trip should be made for the purpose of locating accessible roads; determining whether the ground is suitable for vehicles and the erection of antennas; and determining the amount of clearing needed to prepare the site. Under ideal conditions, where portable beam-antenna equipment and sufficient time are available, a further

check on signal attenuation may be made between adjacent sites.

23. Siting by Radio Altimeter

a. In areas where accurate contour maps are not available, the altimeters on Army airplanes and helicopters may be utilized to profile a proposed vhf hop. Either the aneroid (pressure) or the radio altimeter may be utilized for this purpose. Initial readings should be taken at each end of the hop; subsequent readings taken at significant terrain features in a straight path between the two ends of the hop then may be plotted on 4/3 earth radius paper (DA Forms 11-47 and 11-48). In using these data, just as with profiles developed from contour maps, the curvature of the earth and the average refraction may be computed. The earth's curvature, plus atmospheric refraction will effectively elevate an obstruction several hundred feet higher than it actually appears on flat earth, or on a rectangular coordinate profile. This is especially true where a long hop is involved.

b. Aerial photographs are useful in determining locations of roads, power lines, or other details which may affect the site choice. In the final analysis, however, an on-the-spot inspection of the site is most desirable, since this will reveal problems which would not otherwise be apparent.

24. Accessibility of Sites

a. One of the most important considerations in selecting radio repeater sites is *accessibility*. Where no road exists to a proposed site, a field trip will be required to determine the amount of

work necessary to establish accessibility. For rolling terrain, road construction may not be too difficult, whereas in rocky, hilly terrain more serious problems will be met. Often it may be more advantageous to select another site, less desirable from a radio standpoint, rather than attempt to establish accessibility at the *best* site. Such problems, however, involve both tactical and logistical considerations. In hilly country, landslides and washouts hamper operations and provide a hazard for operating and maintenance personnel. The quality of the access road will depend primarily on the amount of use it will receive—equipment powered by engine generators requires frequent trips with fuel.

b. Emergency and routine supply by helicopter is worthy of consideration in cases where tactical requirements justify sites located in otherwise inaccessible locations. The two significant questions are: Can a helicopter land? If not, can it approach the site close enough to drop supplies?

25. Power Considerations

The reliability of the radio repeater—and therefore of the entire system—is dependent upon the source of *power*. Maintenance and operating procedures as outlined in SOP's and equipment manuals should be rigidly adhered to for reliability of operation. If a power line is available at a proposed site, it should be carefully appraised to determine whether the line is capable of carrying the additional load of the radio repeater. The power should be regulated, both in frequency and

voltage, and the wires should be large enough to carry the added load without excessive voltage drop. In any case, standby engine generators must be available and in operating condition, and must be regarded as the *primary* source of power.

26. Polarization of Antennas

a. General. For practical purposes, radio waves in the vhf range transmitted from a vertical antenna usually are regarded as being vertically polarized, while those from a horizontal antenna normally are regarded as being horizontally polarized. Either type of polarization may be used for vhf transmission, but the performance of each will vary with different conditions. For best results, the orientation of the receiving antenna ordinarily should be the same as that of the transmitting antenna.

b. Advantages of Vertical Polarization.

- (1) Simple vertical dipole or whip antennas are nondirectional in a horizontal plane. This feature is advantageous when good communication is desired in several directions from a radio set.
- (2) Where antenna elevations do not exceed 10 feet, vertical polarization in the 50- to 100-mc band results in a stronger signal than can be obtained from horizontal polarization using antennas of the same height. However, this difference is negligible when using frequencies higher than 100 mc.
- (3) For transmission over sea water, verti-

cal polarization is better than horizontal polarization when antennas are below a certain elevation. This elevation is about 50 feet at 85 mc and lower at the higher frequencies. This means that with ordinary antenna mast heights of 45 feet, vertical polarization is better at frequencies lower than 100 mc. At higher frequencies, there is little difference.

- (4) From limited observations, it appears that vertical polarization is less subject to variations in received field intensity such as those caused by reflections from aircraft flying over the transmission path. In locations where aircraft traffic is heavy, this becomes an important consideration.

c. Advantages of Horizontal Polarization.

- (1) A simple horizontal antenna pointed east and west, for example, transmits and receives best in north and south directions and performs poorly by comparison in east and west directions. This inherent directivity is sometimes of advantage as a means of minimizing interference.
- (2) Horizontal antennas are less apt to pick up man-made interference, which ordinarily is vertically polarized.
- (3) Indications are, that when antennas are located in fairly dense forests, horizontally polarized waves usually suffer

lower losses than vertically polarized waves; this is especially true in the higher portion of the vhf range. For any small change of antenna location in moderately wooded areas, the standing wave effects of vertically polarized antennas will cause relatively large changes in field intensity; under the same conditions, these adverse effects are not so pronounced on antennas horizontally polarized. In very dense jungles, performance generally is poor for both types of polarization.

Section IV. COMPUTING RADIO RELAY PATHS

27. Procedure

The procedure to be followed in planning a single-route radio relay system is outlined in *b* through *g* below. When planning a system of interconnecting or parallel routes, follow the procedure for each route in the system. Also bear in mind the considerations mentioned in section III.

a. Determine specific locations of the terminal points of the radio relay system. These points will be based on tactical and geographic considerations and by the location of the equipments connected to the radio terminals.

b. For each radio relay system, draw a sketch on paper as shown in figure 13. Label the radio terminal at the higher headquarters A and the other point B. Assuming a 30-mile radius as a

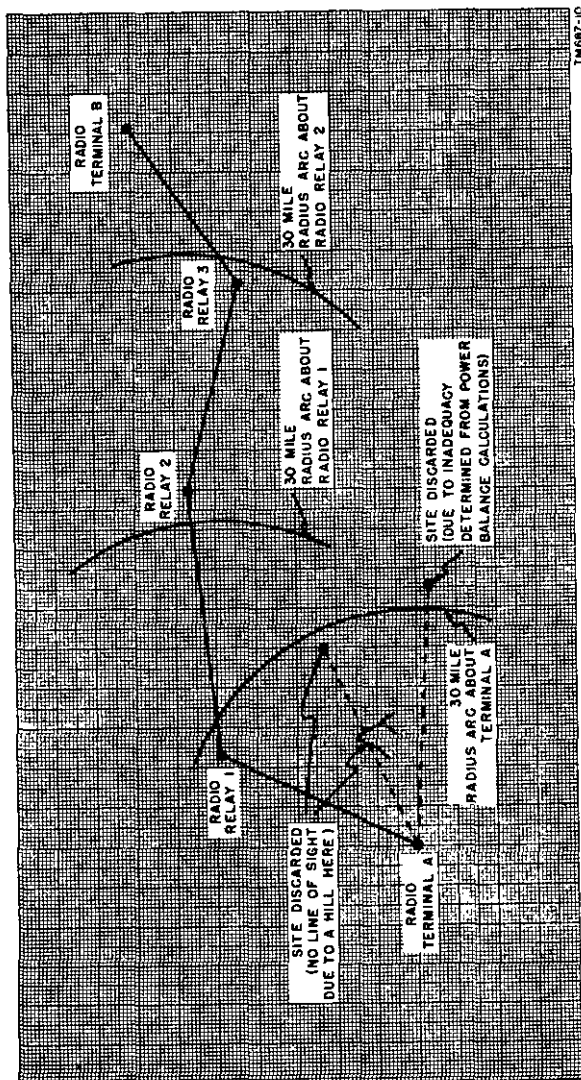


Figure 18. Selection of intermediate radio relay points.

yardstick for propagation distances, use A as the apex and draw an arc of that radius about terminal A and in the general direction of terminal B. Use of an air chart permits rapid visual identification of possible line-of-sight paths since the color contours are easily evaluated.

c. Choose a site with high elevation, on or near the 30-mile radius arc drawn about terminal A. Label this site relay point 1 and draw a profile graph of the ground between terminal point A and relay point 1 (par. 28).

d. Use the procedure outlined in paragraphs 29 and 30 to determine if a line-of-sight path exists between terminal A and the first repeater station. If the site chosen does not give a line-of-sight path, discard the site and select another. Label the site selected relay point 1.

e. If it is impossible to obtain a line-of-sight path between terminal A and any proposed relay point 1, shorten the hop distance by selecting a suitable closer site.

f. When a site has been provisionally selected for a radio repeater, determine by power-balance calculations (par. 31) whether the site selected is adequate. If the calculations indicate that the site is not adequate, discard it and select a new site; repeat the procedure. If very high obstacles are located in the path, refer to paragraph 32.

g. Use the procedure outlined above to determine the sites for all radio relays in the system until the distant terminal is reached. The maximum allowable number of relay points will be determined by the equipment used. Such in-

formation is contained in the equipment manual.

28. Plotting Profiles on Nonlinear Graph Paper

a. To determine that a line-of-sight path exists when choosing a site, draw a profile map (fig. 14) of the terrain between the two proposed sites. Nonlinear graph paper, such as DA Forms 11-47 and 11-48, may be used for plotting profiles from terrain maps. When using graph paper, follow the procedure in *b* through *i* below.

b. Determine from the terrain map the scales used for the distances involved.

c. Draw a line between the two proposed sites (E or H, fig. 14). Measure the length of this line and convert it to the distance between two points.

d. Determine the elevation of each site as indicated by the contour lines. Add the height of the antenna mast to this elevation to determine the total elevation. For example, station N at path D (H, fig. 14) is 1,350 feet high. Assuming an antenna height of 50 feet, the total elevation is 1,400 feet. This point is marked off on the vertical scale of the graph above the zero-mile point (J, fig. 14). Station O has an indicated elevation of 1,400 feet. This height plus an antenna height of 50 feet gives a total elevation of 1,450 feet. This point is plotted on the vertical scale (J, fig. 14) above the 27-mile point, because 27 miles is the distance between the two proposed sites.

e. Draw a straight line between these two points on the profile chart. Check this line and note its lowest point.

f. Draw a complete profile of the terrain between the two sites. Follow the line drawn on the terrain map and pick up high and low points. Plot these points on the graph paper and join them. All points that are above the straight line on the graph (I, fig. 14) represent intervening obstructing terrain.

g. If intervening hills exist between the two proposed sites, as in path C (I, fig. 14), or if the site line is below the curvature of the earth, as in part B (G, fig. 14), poor communication will result. If possible, therefore, use paths such as D (J, fig. 14) where intervening obstructing hills, do not exist, and good communication probably will be obtained.

h. A quicker method of determining line of sight sometimes may be used. After the straight line has been drawn on the profile chart, scan the line and determine the elevation of the lowest point on the line. Next, scan the corresponding line on the contour map and determine whether any point is at a higher elevation than that of the lowest point of the profile-chart line. If there is none, as on path D, a line-of-sight path exists between the end points of the line, and it is not necessary to plot the profile of the intervening terrain. If there are elevations above the point of lowest elevation, as on path C, draw a complete profile to determine whether these high points represent obstructions. For example, the point of lowest elevation on the profile-chart line for path A (F, fig. 14) is 10 feet. On the terrain map, note that path A passes over a portion

of terrain that exceeds 10 feet in elevation. Therefore, it is necessary to plot the profile chart before deciding that path A will provide a line-of-sight path.

i. If the proposed site is intended for a radio repeater station, the transmission path to such site, and also *from* the site to the next radio repeater or terminal station must be considered. It usually is necessary that line-of-sight paths exist in both directions.

29. Plotting Profiles on Linear Graph Paper

If profile graph paper is not available, a profile may be plotted on linear graph paper and then corrected for the curvature of the earth. Use the following chart; then proceed as indicated in *a* through *e* below.

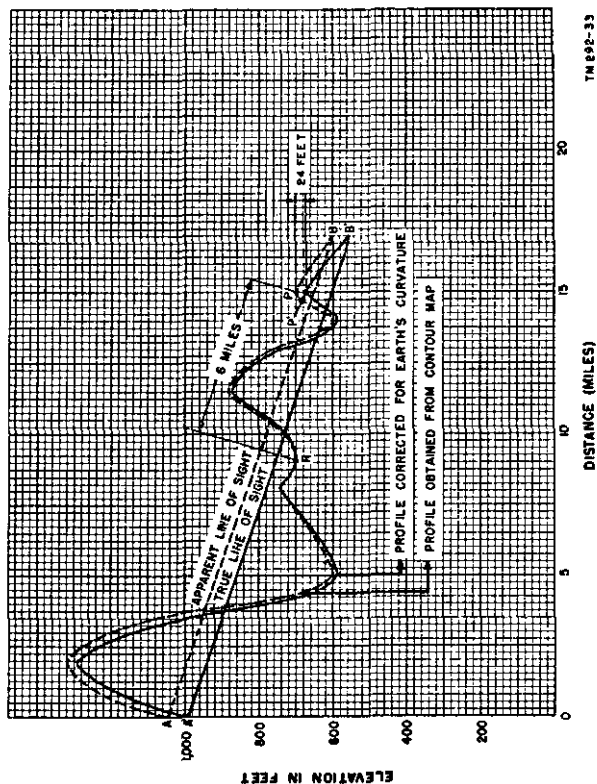
Conversion of Sea-level Elevations to Line-of-sight Elevations

<i>D</i> (miles from reference point)	Elevation correction (ft) (<i>k</i> = 1)	<i>D</i> (miles from reference point)	Elevation correction (ft) (<i>k</i> = 1)
2	3	20	266
4	11	22	323
6	24	24	384
8	43	26	450
10	67	28	522
12	96	30	600
14	130	32	682
16	170	34	771
18	217	36	865

Note. The corrected elevation in feet equals

$$\frac{D^2 k}{1.5}$$

where *k* is the ratio of the effective radius of the earth to the true radius of the earth and *D* is the distance in miles from the reference point. Using 1 for *k* in this formula does not correct for the effect of refraction of the radio wave.



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Figure 15. Plotting profiles on linear graph paper.

a. Determine from the terrain map the scales used for distances and elevations. Draw a line on the terrain map between the two proposed sites.

b. Pick out high and low points along the line and plot these to scale on the linear graph paper. A sample profile is plotted as a broken line curve on this type of graph paper (fig. 15).

c. Draw a line on the graph paper between terminal points A and B.

d. Correction must be made for the curvature of the earth to obtain a true picture of the line-of-sight path. A high or low point is selected as near as possible to the halfway point between the terminals, in this case R. Next, by means of the figures shown in the conversion chart above, the heights of all prominent points in both directions from this central point must be corrected (shown as a solid-line curve). For example, point P shown in figure 15 is 6 miles from reference point R. After correction, P becomes P', 24 feet lower than the original point.

e. Some profile maps will indicate a line-of-sight path with the drawing uncorrected. With correction, however, intervening objects may become apparent.

30. Determining Line-of-Sight Profile Graph

After drawing the profile graph for a particular path and correcting for the earth's curvature (if linear graph paper is used), check the graph carefully to see that a true line-of-sight path exists. The path should not be obstructed in any

way nor should it come closer than 200 feet to any intervening obstructions. If the path is obstructed, discard the site and choose a new one, if possible. If it is still impossible to achieve a line-of-sight path, determine the adequacy of a path from the power-balance calculations (par. 31).

31. Power-Balance Calculations

a. Power-balance calculations are made when planning a system to determine if the *estimated loss* over a particular path does not exceed the *allowable loss* for the path. If the estimated path loss is greater than the allowable path loss, either the path should be changed, the hop length should be shortened, or an intermediate radio repeater should be used. If it is not possible to do any of these things, the hop may be established even though calculations indicate that there will be excessive loss. However, in a system where one or more hops have a greater estimated loss than allowable loss, these hops will limit the operating effectiveness of the radio system. Every effort should be made to reduce path attenuation while *planning* before the actual establishment of the radio relay system.

b. Power-balance calculations performed while planning a radio relay system give only an approximate indication of the system performance. The only way to finally determine system performance is to actually set up the system and test it. If the loss of any particular hop is difficult

to determine from power-balance calculations, the equipment may be installed and tested.

c. Technical circuit criteria for trunking losses are available in TM 11-486-3; path loss information may be obtained in TM 11-486-6.

32. Use of Obstacles to Obtain Long Transmission Paths

Successful vhf communications have been reported over extremely long paths across mountainous terrain, where there was a knife-edge obstacle near the center of the transmission path. In mountainous terrain where such obstacles are encountered, the following procedure may be followed:

a. Place antennas on each side of the obstacle, at equal distances and not too close to the obstacle—signal attenuation increases as antennas are moved closer to the obstacle.

b. Set up the two radio sets, one at each end of the hop, and test the quality of transmission. Vary the height and position of one antenna until a position and height is found where the signal of maximum intensity is received.

c. Use figure 16 to obtain an approximate indication of the path loss due to a very high obstacle. For path lengths of 50 and 150 miles, the chart shows the free-space transmission loss and the smooth earth transmission loss when using the principle of diffraction over high obstacles. The antenna heights are given as 100 feet above the surface. Also shown is the path loss at 50 and 150 miles plotted against the obstacle height.

TRANSMITTING AND RECEIVING ANTENNA HEIGHTS: EACH 100 FEET ABOVE THE SURFACE

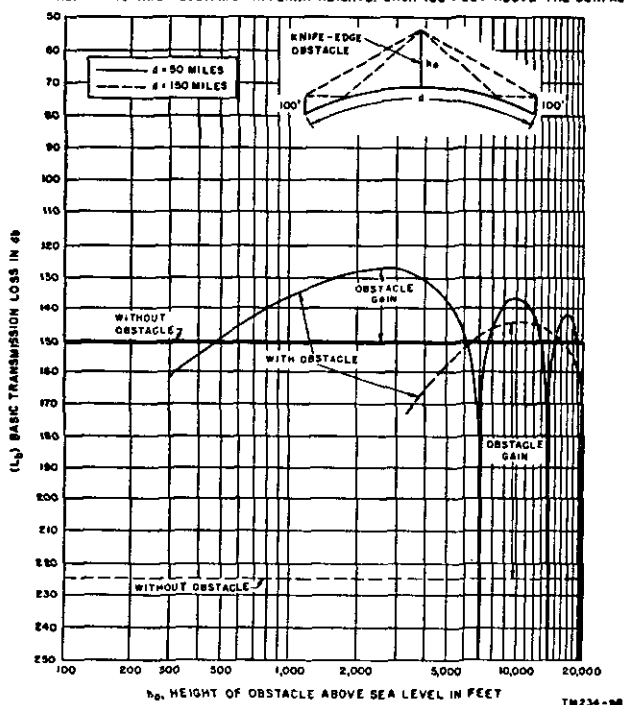


Figure 16. Theoretical obstacle gains at 100 mc.

Section V. SYSTEM RELIABILITY

33. Estimate of Reliability

a. There are many factors other than the possibility of equipment failures to be considered in estimating the reliability of a radio relay system. Transmitter output, distances between stations,

and receiver sensitivity are some of the characteristics that will affect reliability of a system. Other factors, such as reflected or refracted signals, fading due to ionospheric storms, and even seasonal changes in the terrain, can affect the signal strength, and hence affect the reliability. Many of these variables may be eliminated or controlled, however, by careful choice of sites, use of proper equipment, and allowance for fading.

b. One way of obtaining higher reliability is to decrease distance between radio repeaters. Repeater spacing of 30 to 50 miles generally will be satisfactory for frequencies below 10,000 mc, provided good path clearance is available.

c. A signal will be affected by the receiver antenna gain and the transmission line loss between the antenna and the receiver. In order for the signal to be intelligible it must be stronger than the receiver noise level. Manufacturers of the receiving equipment determine a signal level for their equipment which depends on the type of modulation used and the receiver design. This level is called the *threshold level*, and represents the lowest signal level that will be intelligible. Although a received signal may be only barely above this level, satisfactory transmission results, provided there is no fading. Since fading lowers the signal strength at the receiver, it is necessary to have a much stronger signal arrive under normal conditions, in order that an intelligible signal may be received under expected fade conditions. The difference between the field strength of the level normally received and the threshold level

is called the *fade margin*. The field strength to be expected for any radio site can be calculated within ± 5 db by using information from the equipment manual and data taken on the individual hops of a radio relay system.

34. Acceptable Reliability

a. Reliability is determined by the percent of the time that the signal strength at the receiver is above a predetermined level. This level is the signal strength to be expected 90 percent of the time and is independent of the receiver characteristics and fade conditions expected in the area where the radio relay system is to be installed. Should the signal strength be equal to the threshold level of the receiver, the outage time would be 10 percent, and obviously not acceptable. No radio relay system should be planned to operate at the receiver threshold level since a fade of any magnitude would immediately result in circuit outage.

b. By planning the hops so that the signal is higher than the threshold level of the receiver, higher reliability is obtained. This acts as a cushion to absorb fading. For example, if the received field strength at the receiver is -10 decibels referenced to 1 milliwatt of power (dbm), and the receiver threshold level is -50 dbm, the difference, 40 db, is the fade margin for that hop. On the basis of previous experience, it has been found that a 40-db fade may be expected not over .01 percent of the time, so that the 40-db fade margin gives a reliability of

99.99 percent. The relationship between reliability and fade margin usually is given in applicable technical manuals, so that the radio relay system can be engineered for whatever reliability is desired. In most instances, path attenuation will be the greatest source of attenuation, so that where a lower reliability is acceptable, the repeater stations may be spaced farther apart.

c. In calculating the reliability to be expected from a radio relay system, the simplest and safest method is to assume that outages in the various hops will not occur simultaneously. For example, if a radio system has 10 hops, with an efficiency of 99 percent for *each* hop, it is safe to estimate that *each* will be out 1 percent of the time. However, since outages are assumed to occur at different times, the total outage time for the entire 10-hop system then would be 10 percent, so that the system as a whole would have a reliability of 90 percent. As the number of hops increase, however, the likelihood of the outages occurring simultaneously also will increase.

35. Factors Increasing Range or Reliability

There is no method of simply evaluating the effect on a vhf system of such factors as changes in weather or terrain conditions. However, the effect of many other important factors can be evaluated. When installation of radio relay stations beyond the radio line of sight is necessary, the following factors tend to improve performance on either the normal or the obstructed circuits:

a. *Proper Siting.* Careful selection of station sites and particularly the selection of good antenna sites is probably the most important single factor to insure successful radio relay operation. Hilltop installations and well elevated antennas usually provide the best results. Since experience indicates that significant variations in signal strength exist within relatively small areas, it often is profitable to test antennas in other locations in the same general vicinity for maximum signal strength. Similarly, antennas should be tried at several different mast heights in the various locations. Thus, if a specific site proves unsuitable, other acceptable sites may be found in the same vicinity which will prove satisfactory. Locations near hilltops on the hillside facing the other terminal or radio repeater usually are best. Trial and error is an accepted technique in making the final antenna installation. This is especially true for very rough terrain or when only relatively low elevation sites are available. Every effort should be made to locate the antenna above foliage.

b. *Proper Antenna Orientation.* Terrain in the vicinity of either the transmitting or receiving antenna can distort the antenna pattern; therefore, antennas should be experimentally rotated (ch 8) to arrive at the best orientation. Such rotation frequently will reduce the effects of indirect (reflected) signals caused by rough terrain features, such as river valleys or near-by high mountains. Conversely, however, sharp terrain features may be capitalized upon to pro-

vide *usable* indirect radio paths when both transmitting and receiving antennas are properly oriented. Normally, propagation by indirect paths is inferior to that of direct paths, but in some instances circuits can be established through use of such indirect paths where no circuit normally can be realized.

c. Radiation of Strong Signals.

- (1) After the site is selected and the proper antenna orientation determined, the signal level at the receiver will depend on the strength of the radio signal directed toward the receiver location. Vhf systems should be established with the minimum amount of power required for good reception, while at the same time allowing sufficient power to overcome fading due to atmospheric disturbances. This procedure also will minimize adjacent and co-channel interference, reduce the amount of interference between adjacent or interconnected vhf systems, and lessen the possibility of enemy interception.
- (2) If a high-gain antenna, such as a vhf rhombic is used, more of the lower powered signal will be directed toward the receiving site and the effect will be the same as if transmitter power were increased.
- (3) Losses between the transmitter and the antenna may be minimized by using a high quality transmission line as short

as possible and properly matched at both ends.

- (4) When a circuit is subjected to enemy jamming, the change from multichannel to single-channel operation allows more of the transmitter power to be concentrated in the single channel, and thereby improves the signal strength of the channel. (This procedure should be used only under emergency conditions.)
- (5) On marginal circuits, it may be necessary to use an rf amplifier to increase the transmitted power.

d. Use of Lower Level Signals at Receiver.

- (1) The ability of the receiver to operate on a weak signal is directly dependent on the ability of the receiving antenna to capture as much of the signal as possible without picking up excessive noise interference. High gain antennas, properly oriented toward the signal source and situated away from noise sources, will provide better reception than simpler antenna types. The amount of noise picked up by any antenna will increase unless local sources of interference, such as high-voltage transmission lines, ignition systems, or other electrical equipment, are eliminated. In many installations, nearby communication equipment may generate spurious signals which merge into a high background noise level. In some installa-

tions, adjacent channel or co-channel interference will determine the lowest useful signal at the receiving site.

- (2) In addition to external noise, the received signal must compete with noise generated within the receiving set itself. High quality receivers located in an area free from interference and connected to a high gain antenna by a short high quality transmission line will provide the best signals.

CHAPTER 4

FREQUENCY SELECTION

Section I. GENERAL

36. Assignment of Frequencies

a. Problems encountered in planning radio relay systems (ch 3) are similar. The assignment of frequencies, however, imposes a particular problem especially when a large number of radio relay systems are concentrated in one area. As a consequence, the selection and assignment of noninterfering frequencies become proportionately more difficult. Scarcity of available frequencies may even require changes in choices of station locations to help reduce interference.

b. Some of the factors to consider in choosing frequencies for a single vhf radio relay system are as follows:

- (1) Separation between transmitter and receiver frequencies at a given station.
- (2) Separation between receiving frequencies at the station.
- (3) Re-use of frequencies.
- (4) The type of equipment used.

- (5) Generation of harmonics by equipment.
- (6) The nature of the traffic to be sustained.
(At certain frequencies, high-grade transmission is difficult.)
- (7) Relationship of frequencies used by an adjacent system or systems in a given area.

37. Frequency Characteristics

Frequencies above 30 mc usually do not have long-range propagational characteristics and therefore may be used simultaneously by many units throughout a theater with a minimum of interference. When there is some freedom of choice, frequencies that are best propagated should be selected: Higher frequencies should be selected for short hops and for hops over smooth terrain; lower frequencies should be used for longer hops or for obstructed paths.

38. Minimum Frequency Separation Between Adjacent Transmitters and Receivers

a. At vhf, the transmitting frequencies for radio relay equipment which does not require the use of interference charts (AN/TRC-3 and -4; and AN/GRC-39 and -40) must be well-separated from the receiving frequencies by a *guard band* to minimize transmitter-to-receiver interference. However, guard bands alone are no absolute guarantee of interference-free systems employing these vhf sets. The transmitter frequencies are kept on one side of the guard band and the receiving frequencies on the other side.

b. The receiving frequencies at a station must be well separated from each other to prevent receiver-to-receiver interference. Usually this is done by operating the receivers so that at least one unused frequency channel separates the operating frequencies between any two receivers.

39. Frequency Plan Flexibility

a. Frequency plans should be flexible so that the system layout may be changed on short notice, and so that the frequencies of the stations that are moved will be compatible with the frequencies in use at the new locations. Flexibility in the plans is increased by the following:

- (1) Providing ample frequencies.
- (2) Avoiding frequencies that presuppose particular physical arrangements.

b. Factors that may affect the assignment of frequencies are—

- (1) Terrain obstacles between higher and lower headquarters. Circuits originally installed over a direct path may require radio repeaters if such headquarters displace to new locations. Such repeater frequencies must be compatible with associated terminal frequencies.
- (2) Lack of alternate means of communication may require that all trunk circuits be provided by radio relay systems. This situation may necessitate many changes in radio relay system arrangements. A flexible frequency plan makes such rearrangements easier.

40. Methods of Frequency Selection

The method of frequency selection depends primarily on the kind of equipment used and the physical make-up of the radio relay network. The methods for each equipment is described in the technical manual covering the equipment. An example of such a method is given in paragraphs 41 through 43. For a more complex communication network having parallel and inter-connecting or crossing systems, the method of frequency selection described in paragraphs 44 through 55 is used.

Section II. DIVISION AND CORPS LEVEL

41. Selection of Receiving Frequencies

Observe the following rules when selecting the frequencies of receivers that are to be operated at the same location as the transmitters. Because these frequencies will be transmitting frequencies at some other location, the rules for transmitting frequencies also may apply (par. 42), depending on the location of the transmitters to which the receivers will be tuned.

a. Do not use frequencies for any two receivers at the same location unless the frequencies are separated by the minimum spread recommended in the equipment manual. Minimum frequency separation may be reduced through use of cross-polarization, separation of antennas by greater distances, and reorientation of antennas.

b. Do not use a frequency for a receiver unless

1		2		3		4
Transmitter		(Column 1 multiplied by 2)		Subtract from column 2:		(Column 2 minus column 3) Do not use for receiving frequencies at same site.
Designation	Frequency			Transmitter	Frequency	
A	65.6	131.2		B	66.1	65.1
A	65.6	131.2		C	66.5	64.7
B	66.1	132.2		A	65.6	66.6
B	66.1	132.2		C	66.5	65.7
C	66.5	133.0		A	65.6	67.4
C	66.5	133.0		B	66.1	66.9

it is separated by the minimum allowable amount from a transmitting frequency at the same location.

c. Especially for equipments that do not contain rf filters as a built-in feature, try to keep third-order interference at a minimum. For example, assume three transmitting frequencies, A, B, and C, at one location. Select one of the transmitting frequencies and multiply it by 2. From the result, subtract one of the other transmitting frequencies and record the difference. In turn, subtract the other transmitting frequencies from the result and record the difference. Repeat this procedure for the remaining transmitting frequencies; multiply each by 2 and, in turn, subtract the other transmitting frequencies from the result. If possible, do not use any of the final answers for receiving frequencies at the same site where the transmitting frequencies are to be used. A detailed procedure for this type of calculation is shown in the chart below: transmitter A operates at 65.6 mc, transmitter B at 66.1 mc, and transmitter C at 66.5 mc.

42. Selection of Transmitting Frequencies

a. Use frequencies separated by at least the minimum amount recommended in the equipment manual.

b. Whenever possible, use only the operating frequencies recommended—do *not* use borderline frequencies (par. 43b).

c. When selecting frequencies to be used at one location, divide the assigned frequencies into two

blocks; let one block contain the higher frequencies (transmitter), the other block the lower frequencies (receiver).

d. If possible, do not repeat a transmitting frequency in any one complete relay circuit. If scarcity of available frequencies dictates such repetition, a minimum of 3 hops separation should be maintained.

43. Mutual Interference Chart

a. For those equipments which necessitate the use of interference charts, transmitter versus receiver frequencies must be checked, using a chart to determine their compatibility. Figure 17 is an example of a mutual interference chart. Transmitting frequencies are shown along the scale at the bottom edge of the figure; receiving frequencies are shown along the vertical edge.

b. When two or more transmitters are located in the same area, the *paper strip* method should be applied to the mutual interference chart. To employ this method—

- (1) Prepare a strip of paper about 1 inch wide and long enough to touch the vertical edges of the chart.
- (2) Place the paper strip on the chart, with its lower edge alined with the bottom of the chart.
- (3) Make a mark on the paper strip at each selected transmitting frequency.
- (4) Slowly slide the paper strip upward on the chart. Keep it straight by alining

one end with one vertical edge of the chart.

- (5) As each horizontal row of squares is passed, note the type of square that is showing at each of the transmitting frequency marks. If any of the marks rests on a black square, continue to move the paper strip upward *until all marks rest on white squares*. Squares containing an X indicate a borderline condition. Frequencies indicated by an X may give satisfactory results; however, they are *doubtful* and recommended for use only in cases of necessity.

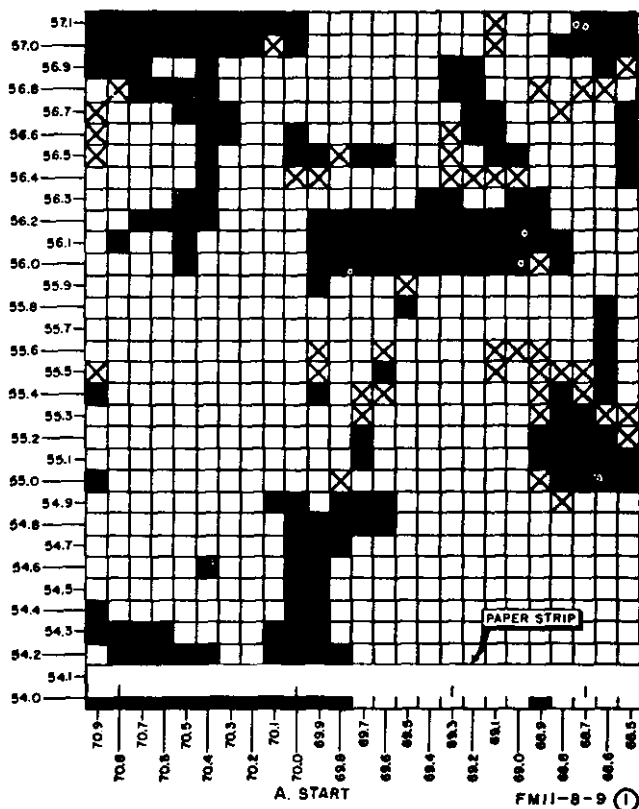


Figure 17. Use of mutual interference chart.

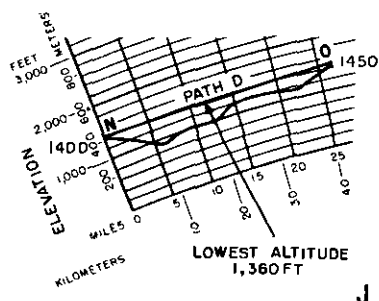
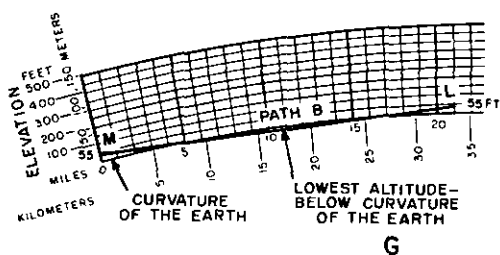
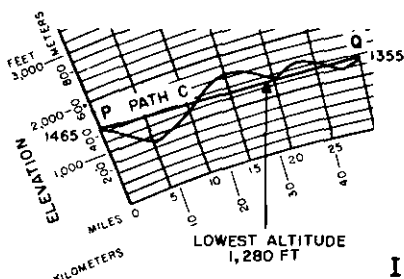
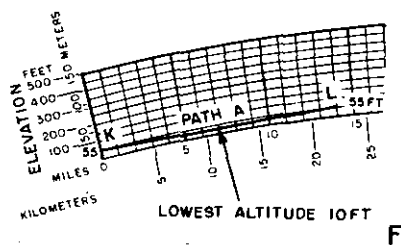
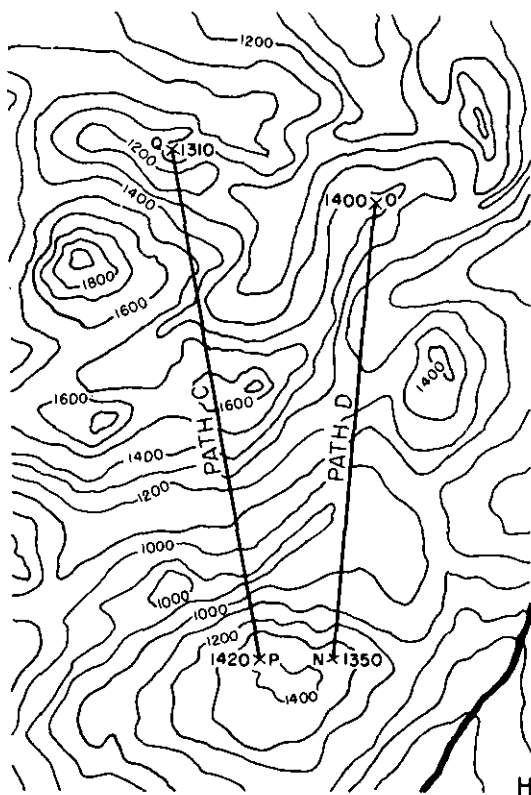
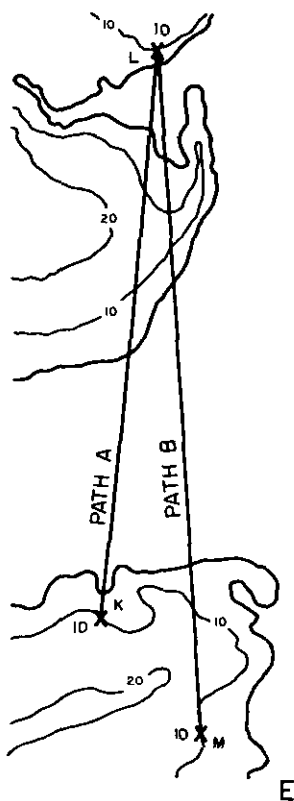


Figure 14. Plotting profiles.

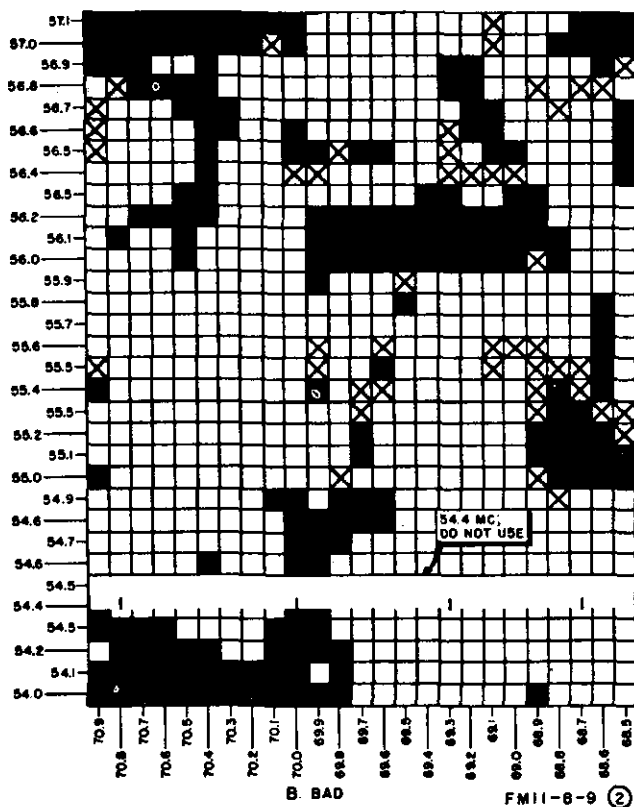


Figure 17—Continued.

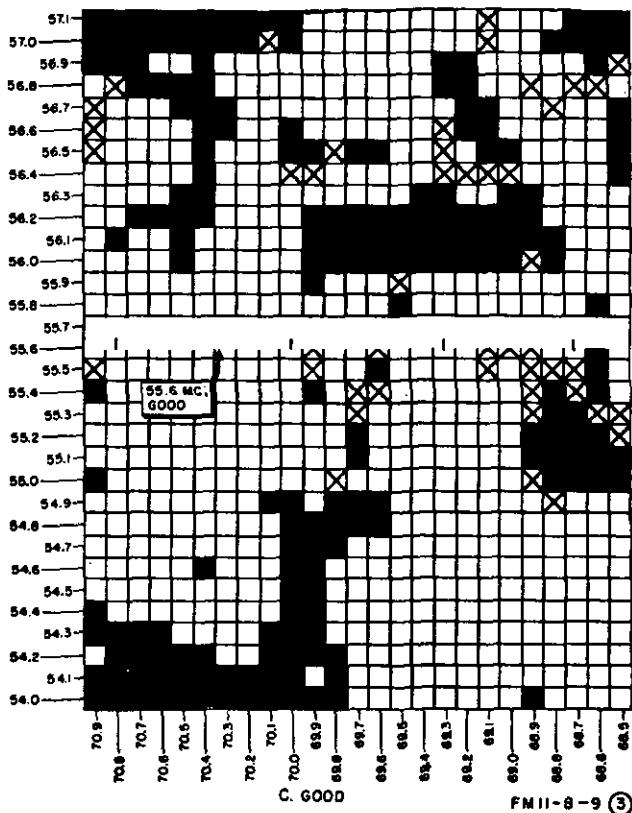


Figure 17—Continued.

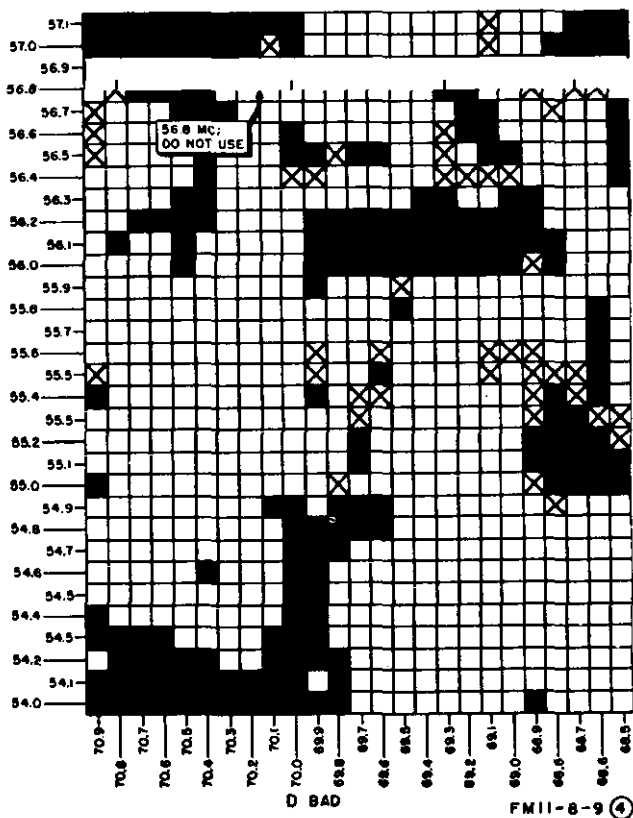


Figure 17—Continued.

Section III. ARMY LEVEL

44. General

The manner of selecting frequencies for equipments that do not require the use of interference charts necessitates a more detailed procedure than the method described in section II. A discussion of the problems encountered in parallel, and interconnecting or crossing systems is given in paragraphs 46 through 48. Specific *plans* for the solution of intricate systems are:

<i>Plan</i>	<i>Paragraph</i>
Abm	49-53
Double-abm	54
Xy	55

45. Two-Block Method of Avoiding Interference

a. The following method of choosing frequencies will give the greatest freedom of tactical action for an isolated route. (An isolated route is one that does not cross or connect with other radio relay routes.) Divide the frequency channels available for use into two *blocks* that contain equal numbers of frequencies. The blocks should be separated by a frequency interval that must be at least as great as the separation required between transmitter and receiver frequencies at any one site. This interval is the *wide guard band* (A, fig. 18). Frequency separation required will be found in the appropriate equipment manual. At each station, assign all transmitter frequencies to one block and all receiver frequencies to the remaining block. The op-

positely directed arrows indicate that in any hop, frequencies in block A are oppositely directed to frequencies in block B. The block diagram in B illustrates the application of the equipment and assignment of frequencies by the 2-block method. Alternate (*frog*) the blocks as shown in C of the illustration. *This is called a 2-block method with wide guard band.*

b. The following is an example of the 2-block method with wide guard band. Assume an isolated route consisting of three hops. The total number of vhf channels needed is $3 \times 2 = 6$. The signal planning officer should request six nonadjacent frequencies, divided into two blocks of three frequencies each. Each frequency must be separated by at least the minimum prescribed in the equipment manual (channel width varies with equipment). Assume that the following frequencies (in mc) are assigned—

<i>Lower block (A)</i>	<i>Upper block (B)</i>
226.5	290.5
229.5	294.5
237.5	300.5

c. For each hop, the planning officer may pick any pair of the frequencies in the manner mentioned in *a* above. No duplicate use of frequency channels should be made in the same general area. If the planning officer is assigned two closely separated blocks, cross-polarization (par. 26) may be used to prevent interference.

46. Parallel Systems

The usual troubles found in parallel systems are similar to those encountered at multiterminal and

radio repeater points. To minimize interference in parallel systems, use the procedure outlined in *a* through *e* below:

a. Determine the number of vhf channels needed for each system on the route by using the 2-block method (par. 45). Allow for expected traffic growth on the route.

b. Work out a tentative frequency plan according to the principles given in the equipment manual.

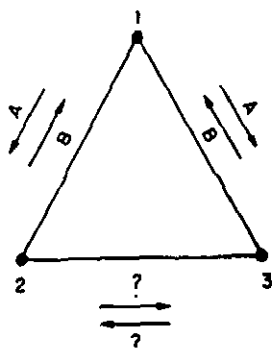
c. Request the necessary vhf channels from the assignment authority. (The channels assigned may differ from those requested so that it will be necessary to work out a frequency plan with those assigned.) If these plans lead to difficulties, use applicable expedients as outlined in paragraph 53. If difficulties continue, try to obtain frequency assignment changes from the assignment authority.

d. As soon as the added (parallel) radio system is set up, operate the equipments to see whether they are free of interference.

e. Try the added system with the existing systems in full operation to determine whether there is any mutual interference.

47. Interconnecting or Crossing Systems

When planning a large number of radio systems that interconnect or cross at various points, the 2-block method may be used. However, the general difficulty that occurs when using this method for interconnecting or crossing systems is that both the transmitting and receiving fre-



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Figure 19. Triangle situation.

quencies planned for a site fall into the same block. This may result in transmitter-to-receiver interference at the site. If the frequency channels on one of the routes are reassigned, the difficulty frequently clears up at one station, but it may reappear at another station. Expedients can sometimes be worked out, but when additional systems are added the difficulty is likely to reappear, forcing another set of frequency changes and another set of expedients. Three different situations are encountered with interconnecting or crossing systems. These are referred to as the *triangle*, *odd-and-even*, and *re-entrancy* situations. They are described as follows:

a. *Triangle Situation.* Figure 19 shows three radio stations interconnected by a single-hop radio system. Assume that only two blocks of frequencies, A and B, are available. If, at station 1, all the transmitting frequencies are as-

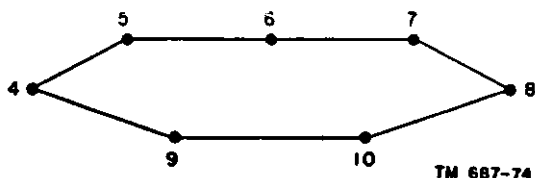


Figure 20. Odd-and-even situation.

signed to block A and all the receiving frequencies are assigned to block B, then:

- (1) At stations 2 and 3, transmitting frequencies are in block B, and receiving frequencies are in block A.
- (2) With only blocks A and B available, there is no simple way of planning interference-free radio communication between stations 2 and 3.
- (3) Trial and error planning may be used with first one selection of frequencies and then another, but this is time-consuming and may fail in the end.

b. Odd-and-Even Situation. The odd-and-even situation is similar to the triangle situation. Figure 20 shows alternate routes between radio stations 4 and 8. One of the routes contains an odd number of hops and the other an even number. Obviously, a difficulty similar to that in the triangle situation exists. Stations 4 and 8 need not be terminals and there need be no through-circuits from station 4 to station 8 to have this difficulty occur.

c. Re-entrancy Situation. The re-entrancy situation occurs when at a given station the same

block of frequencies is used for transmitting on one route and receiving on another. At this station, the communication network is re-entrant. Re-entrancy can be avoided by replacing a radio system by wire on the route or routes that cause the re-entrancy, so that the group of frequencies which are re-entrant are used only for transmitting, or only for receiving at the station. Another solution is the assignment of supplement frequencies, if they are available.

48. Plans for Solving Interconnecting or Crossing Radio Systems

Three plans to solve difficulties with interconnecting or crossing radio systems are the *6-block abm*, *double-abm*, and *xy* plans discussed in paragraphs 52 through 55. The type plan for an area should be chosen before making channel assignments to a particular route in the area.

49. Advantages of Six-Block Abm Plan

This plan is based on a method for dividing a broad frequency region (all or a large part of an allotted band) into six frequency blocks of suitable widths. Vhf channels obtained are divided approximately equally among the blocks. The basic planning is then done in terms of these blocks. This results in the following advantages:

- a. Planning is simplified.
- b. Any station can be connected with nearly any other station with a minimum effect on the rest of the network.
- c. Quick changes are accomplished with minimum effort.

d. Guard blocks at one station are used for frequency assignments at some other station, so that none of the frequency space allotted is barred from use.

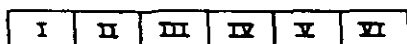
e. It is not necessary to use vhf channels scattered over the whole band.

50. Description of Abm Plan

a. *Block Widths.* For simplicity, consider first the case where the six frequency blocks (fig. 21) are contiguous (touching), so that there is no frequency space between them. The width of each block must then be at least as great as the required transmitter-to-receiver frequency separation for antennas on separate masts. Furthermore, the required separation between receiver and transmitter on the same mast will dictate the total spread of two blocks; that is, the difference between the highest frequency in block I and the lowest frequency in block IV should be at least equal to, or greater than the separation required on the same mast. If any block is not used at a particular station, it will serve as a wide guard band sufficient to prevent transmitter-to-receiver interference at that station. The frequencies in this wide guard band block will be used at other stations in the abm plan.

b. *Abm Blocks.* At the top of figure 21 are shown the six frequency blocks (I through VI). At the left of the figure are shown three *ways* of use for these blocks, namely: *a*, *b*, and *m*. The use of the symbols *a*, *b*, and *m*, is helpful in planning. One symbol is assigned to each radio sta-

**FREQUENCY
BLOCKS:**



**WAYS OF
USE**

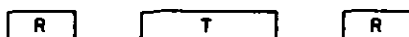
a



b



m



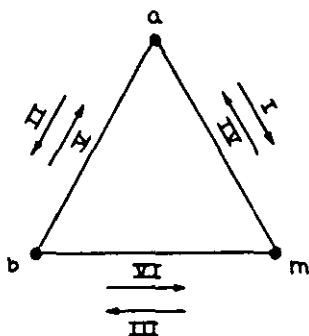
TM 687-75

Figure 21. *Abm plan.*

tion. The symbols identify a block (or blocks) of frequencies that may be used to transmit and/or receive at a station. For example, when way *a* is used at a particular station, the frequencies in either block I or II can be used for transmitting; and those in block IV or V can be used for receiving. When way *b* is used at a radio station one hop away, frequencies in block II or III may be used for receiving frequencies and those in block V or VI for transmitting. Thus, in a single hop between stations *a* and *b*, frequencies in block II may be used to transmit from *a* to *b*, and those in block V from *b* to *a*. Similarly, if the symbol *m* is assigned to a third station, that is one hop from *a* on another route, frequencies in block I may be used to transmit from *a* to *m*, and those in block IV from *m* to *a*.

51. Applications of Six-Block Abm Plan

a. Triangle Situation. The abm solutions to the triangle situation is shown in figure 22. To

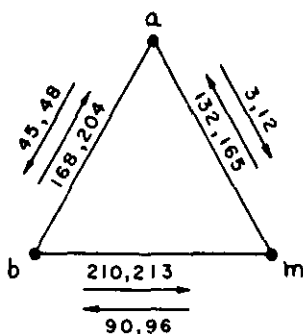


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Figure 22. Abm solution of triangle situation.

solve it, draw a triangle and assign the letters *a*, *b*, and *m*, at the three stations. Any available vhf channels in blocks I through VI may be assigned as shown without transmitter-to-receiver interference occurring. The particular vhf channels assigned must be chosen so that the rules for separation between receiving frequencies at a station are observed. Thus, the abm plan solves the transmitter-to-receiver interference problem automatically.

b. Assignment of Specific Vhf Channels. The following is an example of specific channels assigned according to the abm plan. Suppose that in the triangle situation two parallel radio systems are required on each hop. Use the symbols shown in figure 22, and request two channels properly separated in each of blocks I to VI. Suppose the following channels and their corresponding frequencies are assigned:

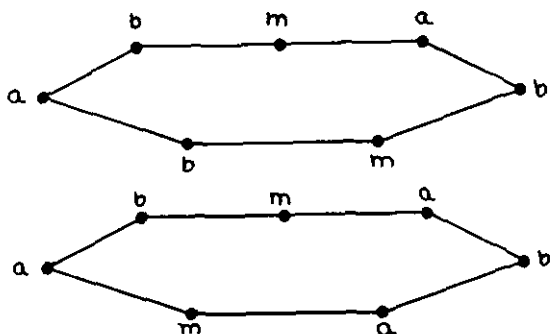


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Figure 23. Sample channels for triangle situation.

Channel No.	Frequency (mc)
3	101.25
12	105.75
45	122.25
48	123.75
90	144.75
96	147.75
132	165.75
165	182.25
168	183.75
204	201.75
210	204.75
213	206.25

c. *Arrangement of Channels.* Figure 23 illustrates how these channels may be arranged. They can be paired in the two circuits in any manner desired. Again, suppose that interference from some unknown source, not traceable, appears in channel 3, so that a substitute channel is needed. Any other available channel in block I, except channels 10, 11, 13, and 14 (which are too close



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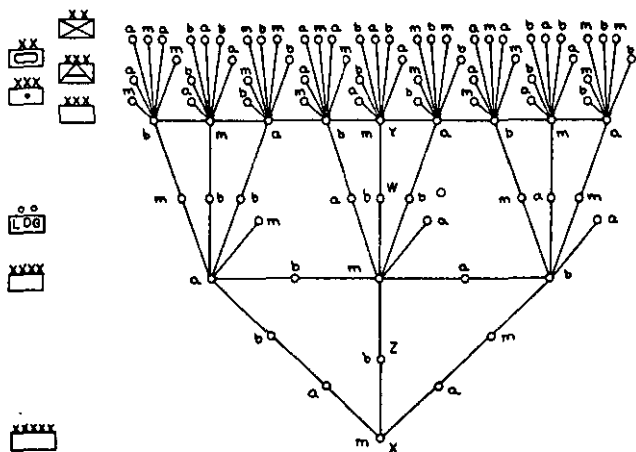
Figure 24. Abm solution of odd-and-even situation.

to channel 12), may be substituted without affecting the rest of the network.

d. Use of Adjacent Channels. Channels 45 and 48 are separated by only 1.5 mc as are channels 165 and 168. Assume that these pairs are under the minimum required separation (2 mc). They may, however, be used by cross-polarizing the antennas (par. 26). Thus the transmitter operating on channel 45 may have a vertically polarized antenna while the one on channel 48 a horizontally polarized antenna. Channels 165 and 168 may be operated in a similar manner.

52. Other Applications of Six-Block Abm Plan

a. Odd-and-Even Situation. Two different methods of assigning abm symbols to solve the odd-and-even situation are shown in figure 24. When using the abm plan for the odd-and-even situation, write out the frequency block layouts



NOTES:

1. O INDICATES RADIO RELAY STATION (INTERMEDIATE OR TERMINAL).
2. O—O INDICATES A HOP WITH ITS TWO STATIONS.
3. EACH SYMBOL a, b, m, OF THE BLOCK, APPLIES TO THE STATION NEXT TO IT
4. SYMBOLS AT LEFT INDICATE MILITARY HEADQUARTERS. EACH SUCH SYMBOL APPLIES TO ALL STATIONS ON ITS LEVEL ACROSS THE PAGE.

FMII-8-10

Figure 25. Sample abm solution of large network.

corresponding to each of ways *a*, *b*, and *m*. Also determine at least one other method of assigning abm symbols to solve the odd-and-even situation. The frequency blocks are automatically arranged to avoid difficulty in choosing vhf channels for any cross-links that may be desired between two radio systems.

b. Large Layout. As a further example, a large layout is shown in figure 25. Only one of many possible methods of assigning *abm* symbols is shown. In practice, some of the hops would be

wire instead of radio, or wire paralleled by a radio system. Also, radio sets using different frequency bands would be used in various places; and additional hops would probably exist, such as those connecting supply points or other headquarters.

c. Noncontiguous Blocks. The edges of successive frequency blocks need not touch each other. The difference between the top frequency used in any block and the bottom frequency used in the block (which is two blocks above it and separated by one other block) should be at least as great as the required transmitter-to-receiver frequency separation. This method assures the required guard band.

d. Multiples of Six Blocks. If adjacent broad bands of frequencies are divided into six blocks each to use in the *abm* plan in the applicable broad band of frequencies, the arrangement for the first six blocks should be repeated in the next six (block VII would be like block I, and so on). This is done to avoid transmitter-to-receiver interference at the common edge of the two broad bands of frequencies.

e. Different Types of Radio Relay Sets. If the frequency widths of the blocks are properly chosen, different types of radio relay sets can share the blocks.

53. Methods of Decreasing Necessary Block Widths

In the 6-block *abm* plan (for general application in an area), expedients to decrease the block

width are more difficult to attain than they are in a simple application to a particular route. Many of the expedients decrease flexibility, and the object of the 6-block *abm* plan is flexibility. The expedients that can be used to decrease the necessary block width are given in *a* through *c* below.

a. Pairing. Pairing of transmitter and receiver rf channels can be used for either the *abm*, double *abm* (par. 54), or the *xy* plan (par. 55). The procedure used is to assign the frequencies in pairs: the lowest frequency in the transmitting block at a station is paired with the lowest frequency in a receiving block. This is called pair 1 and is assigned to one radio set at a station. The next lowest frequency in a transmitting block is paired with the next lowest frequency in the receiving block and called pair 2. This pair is assigned to another radio set at the same station. The same method is used for all the frequencies in the transmitting and receiving blocks at a station. By the use of paired frequencies, the separation of transmitting and receiving frequencies of a hop is greater than that of the block serving as the wide guard band. Thus, the width of the blocks may be reduced.

b. Cross-Polarization. If the frequency width of a particular block is to be reduced by use of cross-polarization (par. 26), the frequencies in the block immediately below it should be polarized oppositely to those in the block immediately above it. The following chart uses this method to reduce the frequency width of all the blocks in two adjacent 6-block units.

Cross-Polarization Chart

Six-block unit						
Block	I	II	III	IV	V	VI
Polarization	H	H	V	V	H	H

Adjacent 6-block unit						
Block	I'	II'	III'	IV'	V'	VI'
Polarization	V	V	H	H	V	V

c. Separation of Antennas. Physical separation of antennas should be used only when necessary to reduce block width in last-minute planning, or in field rearrangement, when interference is experienced.

54. Double-Abm Plan

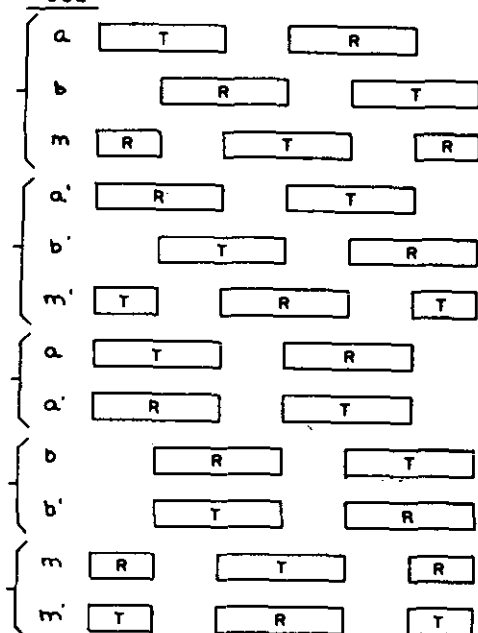
a. Explanation. If the traffic load on a particular route is so great that, with the channels available, use of the *abm* plan becomes difficult, the double-abm plan should be used.

- (1) The double-abm plan uses the same six frequency blocks as the single-abm plan. The double-abm plan uses *ways a, b, and m* of employing these blocks, and also three more ways, *a' b' and m'*. Figure 26 shows all six ways of use. Also it shows that a station labeled *a* can communicate with a station one hop away labeled *a'*. Four of the six frequency blocks can be used for communication between *a* and *a'* (two blocks in each direction). Thus, a heavy traffic route could be made up of radio stations

FREQUENCY
BLOCKS:

I	II	III	IV	V	VI
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WAYS
OF
USE



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Figure 26. Double-abm plan.

labeled a , a' , a , a' , etc. Similarly, b and b' , or m and m' , could be used.

- (2) Suppose that symbol a is assigned to a station S . Then, on a heavy traffic route, the station one hop away from S could be assigned a' . On a lighter traf-

FREQUENCY
BLOCKS:

I	II	III	IV	V	VI
---	----	-----	----	---	----

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Figure 27. *Xy plan.*

fic route, the station one hop away from S could be assigned *b* or *m*.

- (3) The series of symbols with prime and nonprime letters (*a*, *a'*, *b*, *b'* or *m*, *m'*) need not be used for heavy traffic routes only. However, the single-abm series or the single *a'*, *b'*, *m'* series is better for the lighter traffic routes because it permits a greater number of interconnections.
- (4) A route can be made up partly of one series of symbols and partly of another, such as *a'*, *a*, *b'*, *m'*. Symbol shifts of this kind help in making interconnections.

b. Example. As an example of the double-abm plan, consider the case previously worked out in figure 25. If the route from X to Y in this figure were required to carry more traffic than could be handled with available abm frequencies, the double-abm plan could be used on this route merely by changing *b* to *m'* at stations Z and W.

55. Xy Plan

The *xy* plan is used when planning a very heavy traffic route. This plan is not as flexible as the previous plans (abm and double abm) and for flexibility, it relies on interconnection with them. Interconnection between the *xy* plan and the abm or double-abm plan can be worked out by the planning officer.

a. The *xy* plan uses the same six frequency blocks as the abm and double-abm plans (fig. 27). Stations labeled *x* and *y* can communicate with each other (without mutual interference) by using vhf channels in four frequency blocks (two in each direction).

b. If *adjacent* broad bands of frequencies are divided into six blocks each, it is necessary to avoid transmitter-to-receiver interference between blocks VI and VII (VII is block I of the adjacent group). A station using *way x* in one of the broad bands of frequencies should use *way y* in the *adjacent* broad band, and vice versa. This would practically eliminate interconnection possibilities with abm plans, if both *xy* and abm plans were used in both broad bands of frequencies. However, interconnections can be made by placing a guard band between the two broad bands of frequencies and by using *way x* at the same stations in both bands, or by using the *xy* plan in only one of the two broad bands of frequencies.

CHAPTER 5

SYSTEM OPERATING TECHNIQUES

Section I. GENERAL

56. Operating Practices

Uniform operating practices must be established throughout the communication system to assure efficient use of signal personnel and facilities. SOP's must be distributed to all points in the system where personnel operate and maintain communications.

57. Control Stations

a. A circuit *control station* must be designated for each system to simplify circuit management problems and to insure orderly control of operations. The terminal serving the higher, or larger, headquarters usually is designated as the control station. The control station is responsible for supervision of initial and overall tests, coordination of maintenance effort for trouble location and clearance, and temporary circuit reassignment to meet emergency conditions.

b. The control station must maintain a *log* to show which circuits are out of service, the reason for such outage, and the prospects for restoral.

The log also must show when permission has been granted radio repeater stations to remove the circuit for routine tests, to patch in spares, or to perform any operation affecting circuit performance. Copies of all circuit orders must be sent promptly to the control station to insure that control station personnel have accurate information on the condition of assigned circuits.

58. Use of Order Wires

a. To carry out necessary testing functions, *order wires* usually are required between control and subordinate stations. Normal trunk circuits must be made available for maintenance operations between main terminals; this is especially true where large centers of signal communication facilities are involved. Order-wire circuits may be an integral part of the communication equipment, or be a voice channel of the system.

b. Order-wire circuits are required as a communication means during the system lineup. Therefore, it is important to complete lineup of the order-wire circuit before attempting the lineup of the other channels.

Section II. SYSTEM LINEUP

59. General

The overall system must be lined up by adjusting transmission levels at all points in the system, where such adjustments are possible, in accordance with instructions contained in the appro-

priate equipment manual. The overall system lineup consists of the *radio-system lineup*, which is accomplished first, and the *carrier-system lineup*, which is accomplished after the radio-system lineup is completed. Procedures for lineup of both equipments are detailed in the equipment manuals.

60. Control of Lineup

a. All lineups are supervised by the control station, designated *Terminal A*; the remaining terminal in the system being designated *Terminal B*. Where carrier equipment is physically separated from the radio-terminal equipment, the carrier attendants at Terminal A will supervise the overall system lineup.

b. During system lineup, intermediate repeater stations (radio or carrier) report all readings to the control station.

c. Permission to make lineup adjustments must be obtained from the control station. If telephoto, facsimile, or other transmissions that require critical signal levels are being transmitted over the system, the control station must insure that no more than a 2-db change will result in the system as a result of any one lineup.

61. Radio-System Lineup

a. The radio-system lineup is given in *b* and *c* below. This lineup is performed only after the starting procedure, as outlined in the appropriate equipment manual, has been performed for each radio set of the radio system. The lineup in-

sures that the radio system is operating at maximum efficiency prior to superimposing the lineup. If connections to the carrier system have been made, the control carrier terminal must be informed when the radio-system lineup is completed so the overall system lineup may be accomplished.

b. The *radio* lineup procedure is accomplished first in the A-B direction, and then in the B-A direction. When performing the lineup, the controls of the transmitter at radio Terminal A are adjusted first. When this has been accomplished, the control radio-terminal attendant directs the attendant at the next receiver in the A-B direction to adjust his receiver control appropriately. When this has been accomplished, radio Terminal A then directs that the next transmitter in the A-B direction be adjusted. Each successive receiver and transmitter in the A-B direction is lined up in sequence until the receiver at Terminal B is lined up. At this point, radio Terminal B assumes temporary control, and directs the lineup in the B-A directions.

c. After all stations have reported readiness for overall system lineup, the control carrier station is notified.

62. Overall System Lineup

a. The overall system lineup is performed for both the carrier system and the radio system. This lineup is controlled by the carrier terminal designated as the control station. As in the case of the radio system lineup, the carrier system

lineup is accomplished first in the A-B direction and then in the B-A direction. The procedure followed is the same at both terminal and repeater stations.

b. The carrier-system lineup adjustments are made in accordance with the procedure outlined in the equipment manual or SOP's. The step-by-step process for lining up the carrier system is similar to that for the radio-system lineup (par. 61).

63. Monitoring and Operating Checks

Monitoring and operating checks must be performed at periodic intervals. These checks normally are performed while the system is operating and should not interrupt the normal use of the radio and carrier equipment. Equipment manuals and SOP's provide a list of checks to be performed.

64. Circuit Order Tests

a. Overall circuit order tests are required after installation tests have been completed and before the systems, trunks, and circuits are placed in service. These tests are made on trunks that are a part of new installations, are additions to an existing system, or which have been rerouted by wiring changes or by patching. They are made on an overall system basis, from switchboard to switchboard (or, if available, from testboard to testboard).

b. All circuit order tests are under the directions of the control station. The tests include

overall signaling and talking, with supervisory checks being made to assure efficient operation. Adjustment and alinement checks also are made to determine whether facilities meet established performance requirements. Noise measurements are made on long distance networks. If the overall performance requirements are met, the trunks are released for use in the communication network; if not, they are subjected to sectionalizing tests to bring the system up to acceptable standards.

Section III. NOISE AND INTERFERENCE

65. General

The range of radio relay equipment is inversely related to the amount of noise or interference at the receiver location; the more noise or interference present, the shorter the distance that can be spanned satisfactorily. The most objectionable result of high noise level is reduced intelligibility in telephone circuits, and errors in carrier teletypewriter circuits. Unshielded electrical equipment, power lines, motor vehicle ignition systems, certain hospital equipment, and power units are sources of radio noise. Normally, all receiving equipment is set up away from heavy motor traffic routes, and vehicles are not permitted within 200 yards of receiver antennas. Harmonic radiation from other transmitters also may cause considerable interference. The prime requirement

for good communication is a high signal-to-noise ratio.

66. Mutual Interference

a. Spurious radiation refers to signals radiated from the transmitter on many frequencies other than the fundamental or carrier frequency. While these spurious radiations are weaker than the fundamental or carrier frequency, they may be strong enough to cause interference (noise) in near-by receivers. Noise is strongest when the receiver is tuned to a frequency corresponding to one of the spurious transmitter radiations.

b. If these other signals above and below the frequency to which the receiver is tuned are strong enough, they may be amplified to the point where they will render the desired signal unintelligible. It is possible for the local oscillator in a superheterodyne-type receiver to radiate a signal which can cause interference. This is known as receiver radiation.

c. Various ways in which mutual interference can occur are—

- (1) Transmitter fundamental radiation to receiver fundamental response.
- (2) Transmitter spurious radiation to receiver fundamental response.
- (3) Transmitter fundamental radiation to receiver spurious response.
- (4) Transmitter spurious radiation to receiver spurious response.
- (5) Receiver radiation to receiver fundamental response.

d. When receivers are situated close to transmitters, the frequency separation must be greater than normal.

e. Interference caused by spurious radiations of the transmitter being picked up by the spurious responses of the receiver need be considered only when a large number of transmitters and receivers are operated at one site and the received desired signal is weak. No interference of this type will be encountered in a communication system where transmitters and receivers are operated with antennas separated by at least 60 feet and with the receivers operating on strong signals.

67. Operation With High System Noise

a. Occasionally, traffic channel noise is excessive. This may be caused by a higher noise level at one or more radio hops than at others. A hop may have relatively high path attenuation due to a long transmission path or line-of-sight obstructions. A high noise level also may be caused by external sources such as ignition or radio interference.

b. Under such conditions, it frequently will be possible to improve the overall system signal-to-noise ratio. Better reception may be obtained by increasing the signal output of the transmitter and reducing the gain of the receiver where the high noise level occurs.

c. There are limits to signal-to-noise improvement, however. Changing 4-channel output to 1-channel output (or 12- - 4-) will increase the

relative signal-to-noise level. This assumes that all of the transmitter power that was used in the higher number of channels is applied to the lower number.

d. When a particular hop is operating with excessive noise, follow the procedure outlined in the equipment manual.

CHAPTER 6

MAINTENANCE CONSIDERATIONS

Section I. GENERAL

68. Maintenance Plan

a. A properly organized and coordinated maintenance plan is one of the most valuable aids to insure maximum system operating efficiency and minimum expenditure of manpower and materiel.

b. The maintenance goal is to minimize circuit outage and, when such interruptions occur, to correct them and restore service as rapidly as possible.

c. Maintenance forces should be organized, equipped, and trained to isolate and correct equipment failures in a minimum of time. *Preventive* maintenance detects and eliminates potential troubles before they can cause service failures (par. 71). *Corrective* maintenance locates reported troubles and restores the equipment to satisfactory working conditions (par. 72).

69. Factors Affecting Overall Operation and Maintenance

a. *Reliability.* To insure reliable operation, signal equipments are tested and inspected at the

source of supply. Accurate records on equipment performance and the prompt submission of reports covering unsatisfactory equipment performance furnish a guide for future equipment improvement.

b. Installation. Before the equipment is placed in service, proper installation and performance testing procedures must receive careful attention. This is particularly important when the communication channels consist of widely dispersed equipments operated together to make up a circuit or system.

70. Basic Requirements for Maintenance Plan

The essential factors for a well-functioning maintenance plan may be summarized as follows:

a. A well-trained group of radio relay attendants and carrier maintenance personnel are required.

b. Standing operating procedures covering maintenance instructions and testing and repair procedure must be formulated.

c. Tool equipments, test equipments, and spare parts must be provided in adequate quantities and at the right places.

Section II. PREVENTIVE AND CORRECTIVE MAINTENANCE

71. Preventive Maintenance

a. Preventive maintenance is a responsibility of all echelons of operation and maintenance. Its purpose is to disclose and correct incipient

troubles, and it consists of performing those maintenance operations that will prolong the life of signal equipment.

b. The basic principle of maintenance is that the repair will be performed at the lowest echelon when the necessary tools, test equipment, parts, skills, and time are available. Equipment supply manuals SIG 7 & 8's are guides for determining the limits of each echelon of maintenance. The emphasis at user level is prevention rather than cure.

c. Preventive maintenance may be subdivided broadly into three categories as follows:

- (1) Operations directed toward preventing damage to equipment—avoidance of rough handling, proper storage, protection from exposure to the elements, and proper operation.
- (2) Routine operations directed toward prolonging the life of the equipment—lubricating, cleaning, adjusting, and inspecting.
- (3) Periodic performance tests directed toward disclosing incipient troubles; performance tests of telephone trunks, carrier equipments, and radio sets are typical examples. Procedures for these tests are found in the technical manuals covering the specific equipment. When such tests are made, they must be performed under the supervision of the control station, since the tests may involve removing the equipment from service or

otherwise interfering with circuits in use.

d. The functions outlined in *c* above are performed by the operators. Defective equipment found should be replaced with spare equipment, and the defective equipment sent to unit maintenance personnel for repair.

e. Preventive maintenance must be performed on a scheduled basis and should cover a list of work items to be checked daily, weekly, and monthly. DA Forms 11-238 and 11-239 should be used as guides. Keeping comprehensive records of troubles and classifying them by types will aid the signal officer to evaluate the condition of his equipment.

f. When new equipment is received in defective condition or when equipment does not perform satisfactorily, the following will be used for reporting such unsatisfactory condition:

- (1) DD Form 6 (Report of Damaged or Improper Shipment) will be filled out and forwarded as prescribed in AR 700-58 (Army).
- (2) DA Form 468 (Unsatisfactory Equipment Report) will be filled out and forwarded to Commanding Officer, United States Army Signal Equipment Support Agency, Fort Monmouth, N. J., as prescribed in AR 700-38.

72. Corrective Maintenance

Corrective maintenance is the work done to locate and correct troubles which have affected the

operation of circuits or equipment. Usually, corrective maintenance is more time consuming than preventive maintenance, and generally requires that equipment be removed from service. To diagnose and clear troubles efficiently, the repairman must be thoroughly acquainted with the equipment and its components, the functioning of the equipment, and the possible symptoms for the different troubles that may occur. Corrective maintenance procedures are found in the technical manuals associated with the equipment.

Section III. OVERALL AND SECTIONALIZING TESTS FOR TROUBLE CLEARANCE

73. Multichannel Systems

A standard multichannel radio relay system basically consists of the following:

- Radio-terminal sets.

- Radio-repeater sets.

- Telephone carriers.

- Telegraph carriers.

- Ringinɡ equipments.

a. The radio relay portion of the system is shown in figure 1. A simplified block diagram of the carrier portion of the system is shown in figure 28.

b. All operators in a system must be in communication with each other by an order-wire channel (voice channel reserved for operational use). If any of the channels on the 2-wire line side of the telephone carrier are used for voice

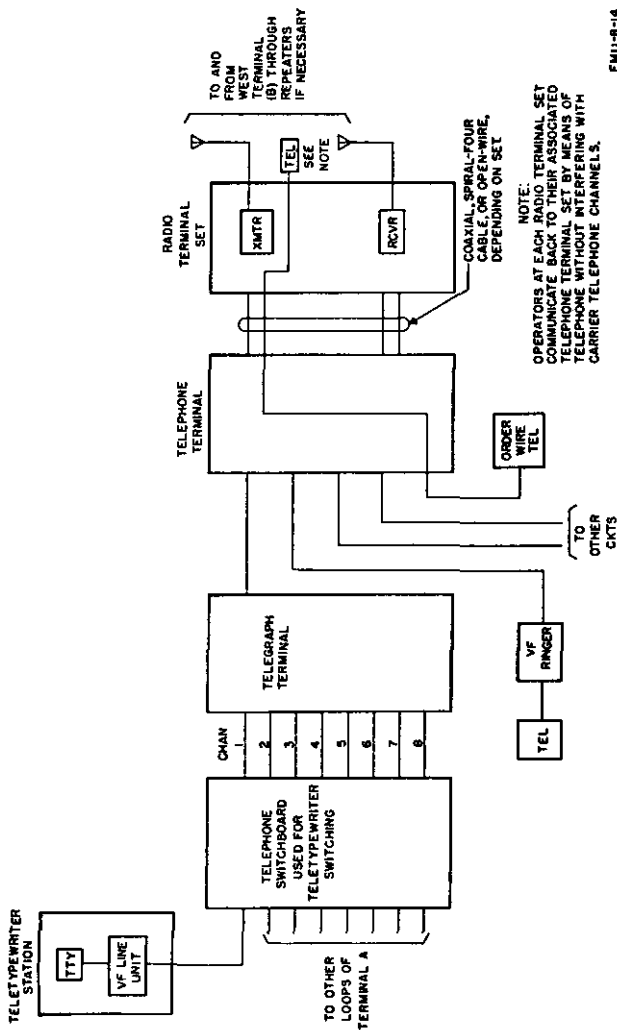


Figure 28. Carrier terminal equipments in radio-relay system.

transmissions, they must be passed through ringing equipment to provide ringing facilities. Telephone channels normally are connected to a switchboard, usually less than 5 miles from the carrier. Channels used for facsimile or telegraph must be strapped around ringing equipment, or connected directly to their respective terminals on the voice-frequency (vf) equipment. Channels used for telegraph transmissions are terminated in a telegraph carrier terminal, from where they may be brought out to a telephone switchboard (used for teletypewriter switching) as shown in figure 28. For simplicity, the telephone circuits on figure 28 have not been terminated in a switchboard.

c. Trouble in the system can be localized by testing the following:

- (1) The radio circuit between terminal stations in both directions.
- (2) The spiral-four circuit between the terminal radio stations and terminal carrier stations at each end of the system.

d. A step-by-step procedure for sectionalizing troubles in c(1) and (2) above is shown in figure 29. This is further described in paragraphs 75 through 77.

74. Long Distance Network

A long distance network comprises the long distance trunk or radio link with its associated central office equipment. The local network comprises the user's equipment and the associated central office equipment and local loops. Overall

tests are used to verify the transmission and signaling features of communication trunks associated with new installations, with additions to the existing plant, and with reassignment of circuits.

75. Overall Tests

a. The overall talking, signaling, transmission, and other tests should be made from switchboard to switchboard under the supervision of the control station. If trouble is encountered, the faulty trunks should be removed from the switchboard, and further tests continued from testboard to testboard.

b. Once a trouble is suspected or reported, overall tests should be conducted to verify the trouble condition. Sectionalizing and localizing tests then should be made to identify and locate the failure point.

76. Station Operation and Maintenance

Overall tests of communication channels include initial and periodic tests to assure serviceability. Adequate testing equipment is required at terminals and intermediate points to perform overall and sectionalizing tests. The facility under test should be removed from service at both terminating switchboards before proceeding with the tests. Under the supervision of the control station, overall signaling, talking, and transmission tests from terminal to terminal should be made first. These are followed by sectionalizing tests between control stations and, finally between relay stations.

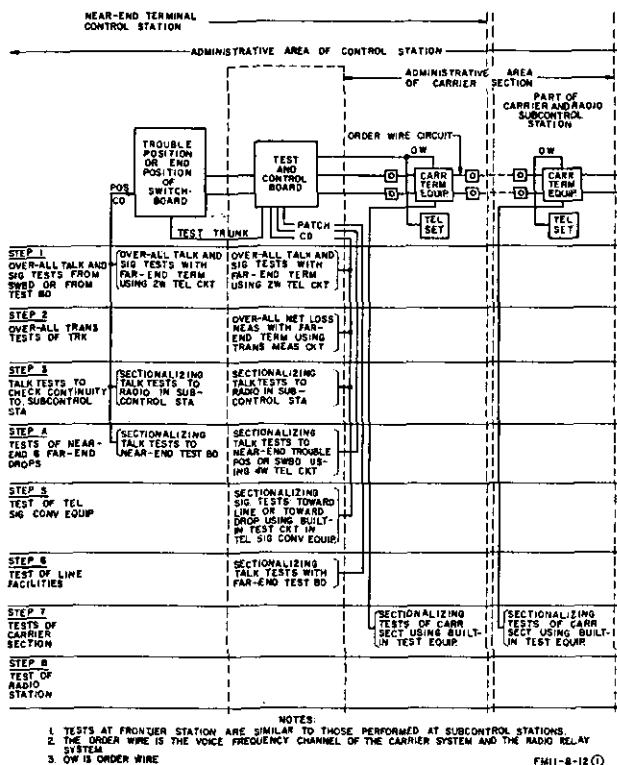
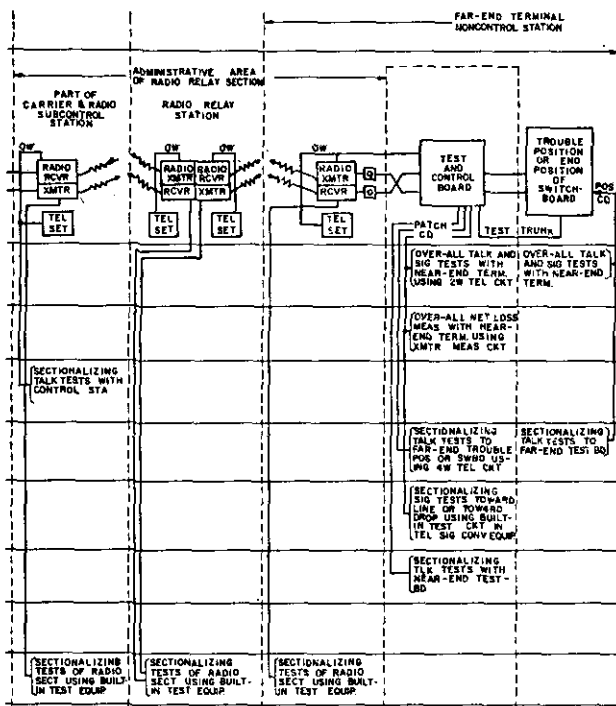


Figure 29. Overall and sectionalizing tests on trunks of radio relay systems.



FM11-8-12(2)

Figure 29—Continued.

77. Test on Trunks of Radio Relay Systems

a. Standing operating procedures must be set up to insure orderly control of maintenance and other work for those long distance circuits which pass through several test or carrier and radio repeater stations in different administrative areas.

b. Overall and sectionalizing tests on trunks of a radio relay system are shown in figure 29. Order-wire circuits often are a built-in feature of military radio relay equipment, as indicated in the figure. The order wires may be extended to order wires of connected systems in the circuit layout.

c. Maintenance personnel are required at all stations in a system to permit coordination of testing activities on long distance trunks and transmission systems. Control and subordinate station procedures must provide for orderly analysis of troubles, and should designate responsibility for placing and maintaining circuits in service. Once a trouble is located, corrective maintenance procedures must be carried out.

d. The areas of responsibility for the activities comprising an integrated radio relay and wire communication system are shown in figure 29. In addition, the procedure and sequence of operations for testing and troubleshooting is outlined in steps 1 through 8 (fig. 29). SOP's must be formulated for forward, intermediate, and rear area radio relay communication systems so that specific responsibilities are assigned to the separate activities of the system. By this means,

troubleshooting and testing procedures may be established and preventive and corrective maintenance performed in a minimum of time and effort.

CHAPTER 7

ANTIJAMMING

Section I. CHARACTERISTICS OF JAMMING OPERATIONS

78. General

Enemy jamming is the transmission of disturbing radio signals to interfere with the reception of the desired signal. The effects sought by the enemy are to disrupt our system and deny its use to our forces. Techniques employed to minimize the effects of enemy jamming are called *anti-jamming*. The term *electronic counter-counter-measures* (eccm) encompasses antijamming.

79. Vulnerability to Jamming

a. All radio relay equipments are vulnerable to jamming activity, and it must be assumed that jamming operations will be conducted by the enemy whenever it is to his advantage.

b. Prior to jamming, the enemy searches the frequency spectrum to locate radiated signals. After identifying a transmission, the enemy tunes a transmitter to the same frequency and transmits a jamming signal. In so doing, the jammer attempts to prevent the effective reception of desired signals on that frequency.

80. Defense Against Jamming

In most instances, antijamming measures will go beyond the efforts of operators. Most present day radio relay equipment has been designed with built-in antijamming features. Special frequency assignments, frequency changes, the use of alternate communication routes, operational adjustments, and the location and destruction of the jamming station are techniques that may be used to overcome enemy jamming. Additional preventive measures include proper siting, use of alternate frequency assignments, code words, and a frequency change system.

Section II. ANTIJAMMING INSTRUCTIONS

81. General

Operator skill and confidence are essential for maintaining communications during enemy jamming. These can be developed by individual, team, and unit training in which simulated enemy jamming is used to approximate actual field conditions. The operator must be familiar with antijamming instructions in the equipment manual and he should refer to FM 11-151, Defense Against Electronic Jamming, for additional information.

82. Instructions for Commanders and Staff Officers

a. If possible, study and plan all operations in advance; use brevity codes to direct plans.

- b.* Keep messages as short as possible.
- c.* Stress radio discipline and security.
- d.* Destroy enemy jamming stations if possible.
- e.* Always inform next higher headquarters of enemy jamming activities.

83. Instructions for Signal and Communication Officers

a. Initial siting is probably the most important and effective antijamming measure that can be taken—it becomes more important the closer radio relay is brought to the enemy location. Where possible, forward area terminals and relays should be chosen with a well-defined land-mass shielding stations from possible enemy interception and jamming. In addition to terrain mass, foliage and man-made structures can be used in achieving this protection.

b. When directional antennas are employed, they can be rotated to minimize the strength of the jamming signal in relation to the strength of the desired signal.

c. Mobile facilities should be relocated to sites where the jamming signal is received at minimum strength.

d. Polarization of antennas may be changed for maximum signal strength (par. 26).

e. Antenna heights may be changed.

f. Where possible, alternate frequencies should be available, and by using spare equipment, the circuit should be re-established on the new frequency, with the original equipment continuing to operate on the original frequency.

g. Circuits should be established on minimum power requirements consistent with circuit quality; high power should be used during jamming to attempt to override the interference. If there are many radio sets in a given area, the SOI should specify, on priority basis, the circuits which will switch to higher power.

h. Generally, forward area radio relay circuits should not be installed in a line perpendicular to the line-of-contact with the enemy. This may be prevented by installing radio repeaters to permit approach to a forward area at an angle. Such equipment utilization must be weighted against all other requirements.

i. Filters should be used, if available, to minimize unwanted signals.

84. Instructions for Operators

a. Site the station and antenna to minimize enemy jamming.

b. Learn to recognize enemy jamming; report all details to the officer-in-charge.

c. Learn to readjust the set to minimize the effects of jamming.

d. Operate with minimum power until jammed—then increase the power.

e. Shift to alternate frequencies and call signs as directed.

f. Authenticate all transmissions over the order wire.

g. Keep the order wire transmissions as short as possible.

h. When jammed, keep calm, keep trying, keep

operating—the enemy may not realize the success of his jamming action and he may shift to another frequency.

CHAPTER 8

FIELD EXPEDIENTS

Section I. GENERAL

85. Definition

a. A field expedient is a positive action that can be taken by personnel to maintain, facilitate, or expedite communications under unusual conditions. These conditions may originate as a result of normal wear or use of equipment, accidental damage, or enemy action. Employment of field expedients requires the application of common sense and ingenuity on the part of personnel immediately concerned.

b. Because of the many possibilities of equipment failure, complete and comprehensive solutions cannot be formulated; however, certain of the commoner field expedients are presented in this chapter.

86. Use of Printed Material

a. Certain former expedients which have proved themselves during field operations and are adopted as official operating procedures are described in Department of the Army publications. Examples of this type literature are TB SIG's.

These bulletins are published to acquaint Signal Corps personnel with difficulties encountered with equipment in the field and to suggest methods of overcoming such difficulties. Usually, they are interim measures and describe corrective action for equipments prior to final publication of MWO's, which are designed to permanently improve the equipment. Such MWO's are official Department of the Army publications which direct, and describe in detail, physical alterations to be made to Army equipment.

b. Published TB SIG's and MWO's are listed in DA Pam 310-4. Communication personnel should familiarize themselves with these publications and take the necessary action.

Section II. CONNECTIONS AND ANTENNAS

87. Coaxial Cable

a. Coaxial cable should be kept off the ground, preferably on fabricated supports; however, in a tactical situation it may be laid directly on the ground to expedite communications. Coaxial cable deteriorates by exposure to the elements, however, and such deterioration results in excessive cable losses. Normally, the proper length cable, as specified in the equipment manual, should be used. During emergencies, longer lengths may be used. Spiral-four cable and field wire may be tried as a substitute for coaxial cable but should be used only when the proper cable is badly damaged or not available. Use of spiral-

four or field wire as a substitute generally results in excessive line losses.

b. Cable connections and fittings on equipment must always be kept clean and dry.

88. Vehicular Expedient for Coaxial Cable

a. Normally, coaxial cable is run from the antenna directly to the equipment inside the vehicle through apertures in the siding. This method results in an unwieldy arrangement of cable and also decreases the dustproof and heat-retaining features of the truck. To correct the situation, a make-shift terminal strip, consisting of a board on which antenna couplings are fastened, may be mounted on the exterior of the truck and the cables connected to the mounted couplings. A short length of appropriate cable may be permanently installed in the interior of the truck, thus connecting the cable to the equipment.

b. For ease in running the cable from the vehicle to the antenna, an appropriate reel unit may be mounted on the rear of the vehicle trailer, using a ground rod as an axle. By this method, the desired length of cable may be payed out, and the coupling taped and connected with ease. This facilitates installation and also helps to prevent knotting and kinking of the coaxial cable—kinked coaxial cable has extremely high rf loss.

89. Effective Protection for Coaxial Couplings

a. Frequently, use of coaxial couplings in field operations has been limited by impairment due to climatic conditions. To eliminate trouble from

this source, use of nonadhesive, polyethylene rubber-and-rosin composition tape, $\frac{3}{4}$ -inch wide, has proved effective. Use of ordinary friction tape generally is unsatisfactory; however, this special rubber tape overcomes coupling troubles effectively.

b. Coaxial couplings protected by this tape can be submerged in water or subjected alternately to freezing and thawing temperatures without adversely affecting transmission qualities.

90. Antennas

Some expedients that may be used for antennas are:

a. Antennas may be installed on a tree, building, house, or similar structure in an emergency.

b. Field wire, rope, or any similar material may be used in place of lost or damaged guy wires.

c. Where the site is located at high elevations, a shorter than normal mast may be used. This facilitates maintenance and orientation, and also any alteration in antenna settings which may be required by change of operating frequency.

d. A standard dipole antenna may be used, if cut to proper length; however, gain and directivity are reduced by the absence of reflector and director elements.

91. Storage for Antenna Guys

Antenna guys may be wound and stored on a 1- by 6- by 24-inch board by making semicircular cuts at each end for winding the guys lengthwise around the board. The guy lengths may be indi-

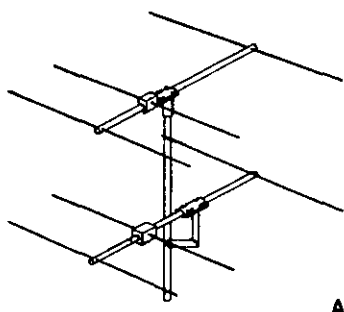
cated on the board and several guys may be wound on each board. These boards may be made to fit the appropriate antenna parts case. This method eliminates fumbling and groping for antenna guys, and facilitates locating guys of appropriate length.

92. Use of Double-Head Mast for Radio Relay Equipment

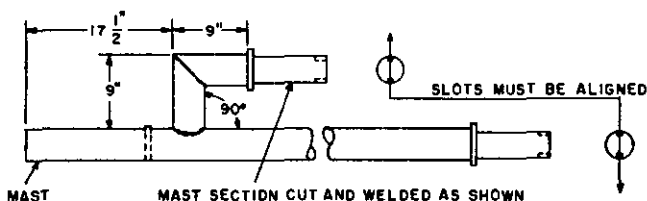
Fifty percent of the time required for assembly and disassembly of antennas of the type used with Radio Terminal Set AN/TRC-3 can be saved by the application of a relatively simple expedient. This requires construction of a double-head mast section, as shown in A, figure 30. Normally, two single masts (one for receiving and one for transmitting) each with a separate antenna head, are required for a terminal. With the use of the double-head expedient, only a single mast is required. Details showing the construction of the double-head mast section are shown in B, figure 30. Field tests indicate no appreciable deterioration of signal quality through use of this type antenna. Where high winds and accumulations of ice and snow prevail, loading considerations must be taken into account.

93. Expedient for Rapid Antenna Installation

If concurrence is obtained from the local ordnance officer, angle-iron may be welded to the front of the standard 2½-ton general-purpose truck. If two or three straps are riveted to this angle-iron, it will be able to support a vhf an-



A



PART OF ANTENNA SUPPORT AB-33

B

FM11-6-16

Figure 30. Use and construction of double-head mast section.

tenna that may be quickly fastened by two men. This support will eliminate the use of guy wires under normal conditions when using short antenna supports. Similarly, straps may be fastened to the rack sides of 1½ trailers to permit the same type of antenna mast fastenings without antenna guy wires.

Section III. POWER SOURCE EXPEDIENTS

94. Method of Reducing Unit Noise at Forward-Area Sites

The procedure outlined below is designed to reduce power unit noise approximately 90 per cent.

a. Construct a dugout with adequate clearance along the sides and top to provide sufficient space for maintenance and ventilation.

b. Locate the dugout preferably on a slight rise or hill so that accumulations of water and rain will be drained off. Construct drainage ditches from the low side of the dugout.

c. Reinforce the sides of the shelter with sandbags, or a wooden or steel framework, to provide support and to prevent cave-ins.

d. Mount the power unit on a platform to protect it from the moisture of the bare earth floor of the dugout.

e. Erect a roof of available material to provide protection from the weather. Allow space for a ventilator shaft to carry exhaust fumes away. (An exhaust system may be improvised by using flexible metal pipes or carrying cases from 155 millimeter shells.)

f. Drape empty sacks or canvas along the roof overhang to muffle generator noise.

g. Camouflage the dugout with available material that matches surrounding terrain.

95. Other Expedients for Power Sources

a. Usually power units that are recommended for specific equipments are best. However, in

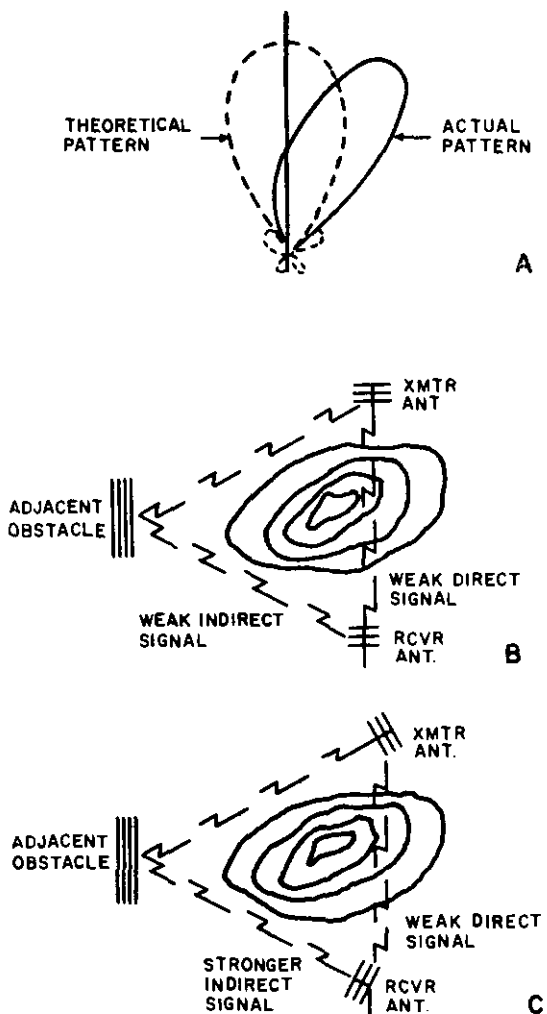
emergency situations any power unit of appropriate output—voltage, current, wattage, and frequency, may be used. Sometimes spare equipments are available to provide additional output power; in such cases, it is recommended that only as many units be used as are required to carry the load.

b. In case of emergency, turn off all equipment and lights except those actually required to keep the circuits in operation.

Section IV. OPERATIONAL EXPEDIENTS

96. Proper Antenna Orientation for Improvement of Marginal Circuits

Terrain in the vicinity of either the transmitting or receiving antenna can seriously distort the antenna pattern so that a weak instead of a strong signal will be received (A, fig. 31). Often the strong signal can be obtained only by trial and error methods. During experimental orientation, advantage often may be taken of *indirect* radio paths utilizing adjacent obstacles such as river valleys or high mountains. In B, figure 31, antennas are oriented for a direct path and a weak signal is obtained because of intervening hills. In addition, part of the signal is reflected by the adjacent obstacle, canceling the direct signal. In C, figure 31, the transmitting and receiving antennas are oriented for the indirect path which results in a relatively stronger signal than that obtained by the direct path.



FM11-8-17

Figure 31. Orientation of transmitting and receiving antennas for indirect signal paths.

97. Improvement of Marginal Circuits

Normally, operating sites should be selected as outlined in chapter 3 of this manual. Under certain situations however, it may not be feasible to locate them within line-of-sight distances. Marginal circuits may result from operation beyond line-of-sight distances. To increase the sensitivity of marginal circuits follow the procedure outlined below.

a. Check and tighten cable couplings and connections.

b. Retune all transmitters and receivers in the circuit.

c. Check to see that antennas are adjusted for proper operating frequency.

d. Try changing the heights of antennas.

e. Try changing locations of antennas.

f. Separate transmitters from receiving equipment, if feasible.

98. Transmission and Reception of Strong Signals

a. After an adequate site has been selected, and the proper antenna orientation obtained, the signal level at the receiver will be proportional to the strength of the transmitted signal. The use of an amplifier at the transmitter provides a stronger signal.

b. Excessive signal strength may result in adjacent and co-channel interference; therefore, the use of an amplifier usually is not recommended. If a high gain antenna, such as a rhombic, is used, a stronger signal can be obtained; thus eliminating the need for an amplifier. Losses between the

antenna and the equipment can be reduced by using a high quality transmission line, as short as possible and properly matched at both ends. When traffic conditions permit, the change from multichannel to single-channel operation will allow more of the transmitter power to be concentrated in the single channel. This will relatively increase the strength of the signal.

99. Mounting of Radio Relay Equipments in Vehicles

Some older type radio relay equipments are not issued with standardized vehicle installation kits. For tactical purposes, it frequently is desirable to mount these equipments in vehicles. Vehicular mounting has both inherent advantages and disadvantages:

a. Advantages.

- (1) Less time and fewer personnel are required for station setup and tear down operations, and station movement.
- (2) Tactical mobility is increased.
- (3) Equipment maintenance time is reduced.

b. Disadvantages.

- (1) General purpose vehicles are converted to a special use.
- (2) Vehicle maintenance becomes a critical factor since the equipments are semi-permanently mounted.

Note. Refer to SB 11-131 for a list of available mounting kits.

100. Operation in Extremely Mountainous Terrain

The following subparagraphs outline useful in-

formation based on operational experiences in mountainous terrain:

a. It is recommended that skid chains be used on vehicles operating on unpaved roads, regardless of the weather conditions.

b. Personnel should be well trained in the use of ropes and pulleys.

c. In hauling and lowering, equipment must be well packaged to prevent damage.

d. At times, radio relay equipment can be operated through masking hills.

e. As a general rule, for every man at the top of a mountain, three will be required for his logistical support.

101. Extension of Order-Wire Circuits

a. It is expedient at times to install an extra physical circuit between the switchboard and the radio carrier terminal. This circuit may be used to extend the carrier order-wire channel to the switchboard to provide telephone service during an emergency when wire communications or other radio telephone channels are out. If this procedure is used, the Signal SOP must specify that only personnel designated by the Signal Officer may authorize the use of these circuits for message traffic.

b. In addition, this circuit may be used by supervisory personnel for control and coordination of the radio relay system from any telephone connected to the terminating switchboards.

c. Some disadvantages to this method of operation are as follows:

- (1) Switchboard operators could disrupt system lineup procedures if the order-wire circuit was used for traffic without getting prior approval.
- (2) While the order-wire circuit is being used for traffic, there is no channel for coordination and control of the radio relay system.
- (3) Additional ringing converters to provide signaling must be installed on order-wire circuits.

APPENDIX I

REFERENCES

1. General

This appendix is a selected list of publications and training films pertinent to field radio relay. For availability of publications and training films on additional subjects, refer to DA Pamphlets 108-1, 310-1, 310-3, and 310-4.

2. Army and Special Regulations

AR 105-15	Field Signal Communications.
AR 220-50	General Provisions.
SR 320-5-1	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations.

3. Field Manuals

FM 11-151	Defense Against Electronic Jamming.
FM 21-5	Military Training.
FM 21-6	Techniques of Military Instruction.
FM 21-30	Military Symbols.

FM 24-5	Signal Communications.
FM 24-18	Field Radio Techniques.

4. Technical Bulletin

TB SIG 66	Winter Maintenance of Signal Equipment.
TB SIG 69	Lubrication of Ground Signal Equipment.
TB SIG 75	Desert Maintenance of Ground Signal Equipment.
TB SIG 237	Microwave Radio Relay Siting.

5. Technical Manuals

TM 11-221	Radio Sets AN/TRC-42 and AN/TRC-47.
TM 11-222-B	Radio Repeater Set AN/FRC-34 and Radio Set AN/FRC-35.
TM 11-486-6	Radio.*
TM 11-614	Radio Set AN/GRC-10, Radio Terminal Set AN/GRC-39, Radio Repeater Set AN/GRC-40.
TM 11-618	Radio Set AN/TRC-8 (XC-3); Radio Terminal Set AN/TRC-11 (XC-3); Radio Relay Set AN/TRC-12 (XC-3).

*Radio manual of Electrical Communications Systems Engineering group of manuals. This manual contains siting, propagation, and antenna design data.

- TM 11-618A Radio Sets AN/TRC-8, -8A and -8B; Radio Terminal Sets AN/TRC-11, -11A, and -11B; Radio Relay Sets AN/TRC-12, -12A, and -12B; and Amplifier-Power Supply Group AN/TRA-19.
- TM 11-666 Antennas and Radio Propagation.
- TM 11-687 Radio Set AN/TRC-24, Radio Terminal SET AN/TRC-35, and Radio Relay Set AN/TRC-36.
- TM 11-689 Radio Set AN/TRC-29 and Radio Repeater Set AN/TRC-39.
- TM 11-2139 Telephone-Terminal AN/TCC-7.
- TM 11-2141 Multiplier Set AN/TCC-13, Multiplier Group AN/TCA-1, and Pulse Form Restorer Group AN/TRA-10.
- TM 11-2239 Telegraph-Telephone Terminal AN/TCC-14.
- TM 11-2242 Telegraph Terminal AN/TCC-4 and Telegraph Terminal AN/TCC-20.

- TM 11-2601 Radio Sets AN/TRC-1, -1A, -1B, -1C, -1D, -1E, -1G, and -1H; Radio Terminal Sets AN/TRC-3, -3A, -3B, -3C, -3D, -3E, -3G, and -3H; Radio Relay Sets AN/TRC-4, -4A, -4B, -4C, -4D, -4E, -4G, and -4H; and Amplifier Equipment AN/TRA-1, -1A, -1B, -1C, and -1D.
- TM 11-2501A Radio Terminal Set AN/TRC-3H, Radio Relay Set AN/TRC-4H.

6. Training Films

- TF 11-1632 The Effects of Ionosphere on Radio Wave Propagation.
- TF 11-1779 AN/TRG—The Radio Relay Systems of Communications.

APPENDIX II **CHARACTERISTICS OF TYPE RADIO RELAY EQUIPMENT**

Radio set	Receiver	Transmitter	No. of rf channels and spacing	Principal uses	Frequency (mc)	Power output (w)	Modulation	Maximum system length ^a (mi)
AN/FRC-23 (terminal set).	Commercial equipment GE model 4UR2B1 or 4UR2B2 (1 ea).	Commercial equipment GE model 4UT2B1 or 4UT2B2 (1 ea).	7 channels 20 mc.	Radio telephone terminal set used in the main axes of communications between large headquarters in the ComZ. Twenty-three 4-kc channels are provided.	1,700 to 1,850.	2	AM-ppm	600

AN/FRC-26 (relay set).	(2 ea of the above.)	(2 ea of the above.)	-----	Radio re- peater set used in systems termi- nated by AN/ FRC-23.	1,700 to 1,850.	2	AM- ppm
AN/GRC-39 (terminal set).	R-125/ GRC-10 (2 ea).	T-235/ GRC-10 (2 ea).	80 channels 200 kc.	Radio set for four- channel point-to- point tele- phone, teletype- writer, or facsimile service; used in most for- ward ele- ments of	54 to 70.9	40	Fm 120
AN/GRC-40 (relay set).	(3 ea of the above.)	(3 ea of the above.)					

Radio set	Receiver	Transmitter	No. of rf channels and spacing	Principal uses	Frequency (mc)	Power output (w)	Modulation	Maximum system length* (mi)
AN/TRC-3 (terminal set).	R-19/TRC-1 (2 ea).	T-14/TRC-1 (2 ea).	300 channels 100 kc.	combat zone; vehicular-mounted for rapid transportation and installation.	70 to 100.	40 (250 with AN/TRC-1).	Fm	250
AN/TRC-4 (terminal set).	(4 ea of the above.)	(4 ea of the above.)		Radio set for point-to-point, radio-relay and radio terminal service. Provides 4-channel				

telephone, teletype-writer, or facsimile service; used to supplement and extend wire lines where speed of movement or terrain prohibits construction. Can be vehicular-mounted or installed in fixed location.

Radio set	Receiver	Transmitter	No. of rf channels and spacing	Principal uses	Frequency (mc)	Power output (w)	Modulation	Maximum system length ^a (mi)
AN/TRC-11 (terminal set).	R-48/TRC-8 (2 ea)	T-30/TRC-8 (2 ea).	20 channels 2,000 kc.	Same as for AN/TRC-3 and -4 except for frequency range; amplifier equipment AN/TRA-19	230 to 250.	5 (75 with AN/TRA-19).	Fm	250
AN/TRC-12 (relay set).	(3 ea of the above.)	(3 ea of the above.)						
AN/TRC-35 (terminal set).	R-417/TRC (2 ea).	T-302/TRC (2 ea).	Band A: 200 channels, 250 kc. Band B: 250 channels,	4- or 12-channel relay system, inter-	Band A: 50 to 100.	50	Fm	400

AN/TRC-36 (relay (set).	(3 ea of the above.)	(3 ea of the above.)	500 kc. Band C: 175 channels, 1,000 kc. Band D: 133 channels, 1,500 kc.	mediate area (theater) communi- cation systems; to replace and sup- plement spiral- four cable circuits where time element prohibits use of wire facilities.	Band B: 100 to 225. Band C: 225 to 400. Band D: 400 to 600. (Bands A and D not devel- oped yet.)
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Radio set	Receiver	Transmitter	No. of rf channels and spacing	Principal uses	Frequency (mc)	Power output (w)	Modulation	Maximum system length ^a (mi)
AN/TRC-38	R-418/G (2 ea).	T-303/G (2 ea).	23 channels. Single band of 30 cps to 4.5 mc.	Wide band radio-relay equipment for transmission of multiplexed voice channels, data, or wide band services up to 4.5 mc; 23-channel terminal set; includes two AN/	1,700 to 2,400.	10	Ppm (pcm with AN/TCC-15 and AN/TRA-18).	600 ^b (up to 19 repeaters).
AN/TRC-39	(3 ea of the above.)	(3 ea of the above.)						

TRC-29 (1 in use, 1 spare) and one AN/ TCC-13. 23-channel radio re- peater set; includes three AN/ TRC-29; operates as a straight video re- peater.	
AN/TRC-40	2-channel- drop re- peater set; includes three AN/ TRC-29

Radio set	Receiver	Transmitter	No. of rf channels and spacing	Principal uses	Frequency (mc)	Power output (w)	Modulation	Maximum system length ^a (mi)
AN/TRC-41				and one Pulse Form Restorer Group AN/TRA-10.				
				8-channel-drop repeater set; includes three AN/TRC-29 and Multiplex Set AN/TCA-1.				

^a These maximum ranges can be obtained only with careful path layout and under reasonably favorable conditions.

^b Range depends on some special provision which is essential to permit maximum range; for example, use of high-power option; or use of pulse-form restorer.

APPENDIX III

PHYSICAL SECURITY

1. Security Factors

Radio relay repeater stations in isolated areas must have adequate security to insure continuous operation. This security can best be attained by establishing a perimeter defense. Security factors to be considered are outlined in *a* through *c* below.

a. Terrain. Defense against enemy attack may be improved by taking advantage of natural terrain features.

b. Vulnerability. The location of the site with relation to its proximity to enemy forces will influence the extent of the defensive measures required.

c. Tactical and Logistic Requirements. Tactical requirements, such as the availability of personnel and materials must be considered when planning perimeter defenses. If the site cannot be reached by vehicle then air drops may be required.

2. Preparations for Defense

a. Immediately after occupying a site, personnel not engaged in establishing communications

should start the preparations for perimeter defense. A reconnaissance of the area must be made to determine the best location for the perimeter defense line. Some of the factors that affect this location are—

- (1) Critical terrain features around or near the site.
- (2) Locations for good observation and fields of fire.
- (3) Locations that offer the best camouflage and concealment for personnel and equipment.
- (4) Advantageous locations for obstacles.
- (5) Protection against the best avenues of enemy approach.

b. Obstacles that may be used in the perimeter defense are—

- (1) Tactical barbed wire (double-apron and concertina).
- (2) Trip firing devices attached to grenades, flares, or dynamite.
- (3) Antipersonnel and antitank mines.
- (4) Barricades and other applicable field fortifications.

c. Augmentation of the defense personnel by Infantry (or other available troops) may be necessary. Such an augmentation would permit radio relay operation personnel to devote full time to primary duties.

3. Example of Typical Radio Repeater Site

Assume that a team of six men are assigned to operate a radio repeater site only a few miles from

enemy territory. The site is subject to raids from guerilla or enemy patrols and is situated at the top of a high ridge, where there are many avenues of approach for enemy attack. This arrangement is depicted in figure 32. Defense positions are located so that personnel may be rotated to defend the sector under attack. A roving sentinel is assigned to alert the remainder of the crew in event of attack. Note that emplacements are located so that guns and personnel may take up positions to defend any sector. Through the proper arrangement of obstacles and deployment of personnel, the 6-man crew may be capable of resisting enemy attack from any direction for a limited time. The use of bunkers for protection against grenades and mortar fire, mines and booby traps well out in front of positions, and pits and holes cleverly concealed afford maximum physical security.

4. Camouflage, Cover, and Concealment

Strict compliance with the principles established in FM 5-20, Basic Principles of Camouflage, is mandatory. In certain cases complete camouflage is impossible; for example, camouflage material may seriously attenuate antenna signal strength. Antenna masts and guys, may be camouflaged with no adverse effects.

5. Defense Against Air Attack

Ground defense against air attack includes both active and passive measures.

a. Active measures against air attack consist

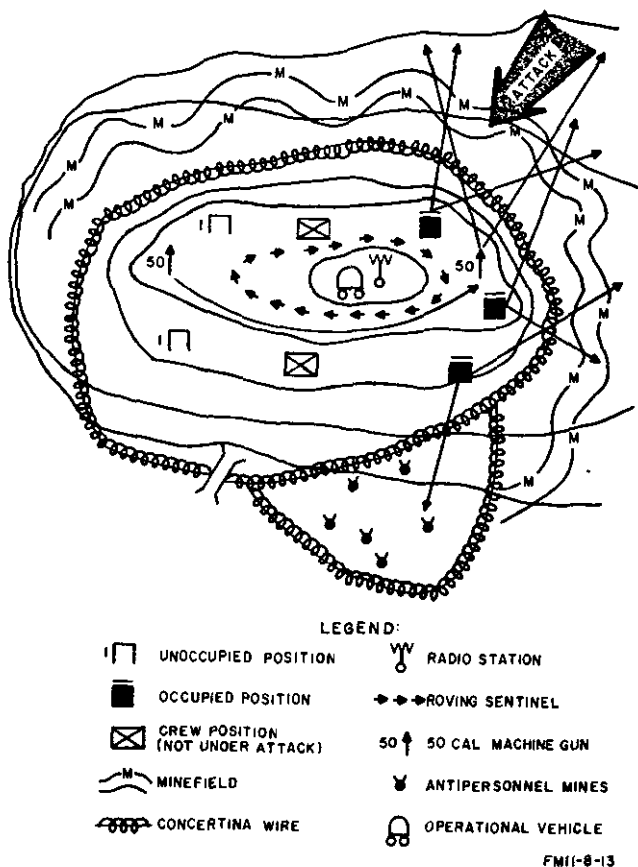


Figure 32. Physical security for radio repeater sites.

of concentrated fire from small arms and machine guns. Since attacking aircraft are a target for only a few seconds, all available weapons must be brought into action promptly.

b. Passive measures against air attack include—

- (1) Dispersal of facilities within an area.
- (2) Camouflage of vehicles and equipment by concealment or deception.
- (3) Use of terrain features to provide concealment.
- (4) Rigid blackout discipline.
- (5) Control of the use of fire to avoid disclosing positions by smoke or flames.

6. Destruction Plans

a. In a retrograde movement equipment facilities and supplies that cannot be evacuated are destroyed to prevent possible use or study by the enemy. Destruction of facilities and supplies is authorized only by the commander and is done according to an approved destruction plan.

b. A well prepared destruction plan is detailed and comprehensive. It contains instructions that are easy to perform, and is consistent with procedures prescribed in equipment technical manuals.

c. Destruction must be performed as rapidly and be as thorough as time permits.

APPENDIX IV

GLOSSARY OF TERMS

- Absorption*—The loss of radiated energy due to dissipation in a conducting medium.
- Amplification*—The process of increasing the electrical strength of a signal.
- Antenna*—An electrical conductor or a system of conductors used to radiate or receive radio waves.
- Array (antenna)*—An arrangement of antenna elements, usually dipoles, to achieve desirable directional characteristics.
- Attenuation*—The reduction in strength of a signal.
- Authentication*—A security measure designed to protect a communication system against fraudulent messages and other transmissions originated by the enemy.
- Axis-of-communication*—The line or route on which lie the starting position and probable future locations of the command post or a unit during a troop movement. The main route along which messages are relayed or sent to and from combat units in the field.
- Band of frequencies*—The range of frequencies between two specified limits.

Carrier frequency—The frequency of the wave which is modulated by the intelligence wave.

Channel—A band of frequencies used for communication.

Circuit—A communication link between two or more points, capable of providing one or more communication channels.

Coaxial cable—A transmission line consisting of one conductor, usually a small copper tube or wire, within and insulated from another conductor of larger diameter, usually copper tubing or copper braid. Radiation from this type of line is practically zero. Coaxial cable is also called concentric line.

Command post (CP)—The establishment set up by the forward echelon of a headquarters during combat, from which tactical control normally is exercised and to which tactical information is sent by subordinate units.

Communication center (comcenter)—A communication agency charged with the responsibility for receipt, transmission, and delivery of messages. It normally includes a message center, cryptocenter, and transmitting and receiving facilities.

Conductivity—The relative ability of a material to allow the flow or passage of an electrical current.

Critical frequency—The limiting frequency below which a radio wave is reflected by, and above which it penetrates, an ionospheric layer.

Cross-modulation—Modulation of a desired signal by an undesired signal.

Decibel (db)—The standard unit of comparison between two quantities (ratios) of electrical or acoustical power.

Demodulation—The process of recovering the audio component (audible signal) from a modulated rf carrier wave.

Dielectric—An insulating material between the plates of a capacitor.

Dipole antenna—Two metallic elements placed end to end, each approximately one-fourth wave length long.

Distortion—Distortion exists when the output wave form is not a true reproduction of the input wave form. Distortion may exist because of transmission or amplification irregularities in amplitude, frequency, or phase.

Duplex operation—The operation of radio equipment in conjunction with equipment at another location in which the process of transmission and reception are concurrent.

Electromagnetic field—The magnetic field that an electric current produces around the conductor through which it flows.

Facsimile—A system for the transmission of still pictures or printed matter by means of electrical impulses that are controlled by a photoelectric cell and reproduced at the receiver by a mechanical device.

Fading—Variations in the strength of a received radio signal caused by changes in the characteristics of the propagation or transmission medium.

Frequency—The number of complete cycles per second existing in any form of electrical or sound wave motions.

Frequency distortion—Distortion that occurs as a result of failure to amplify or attenuate equally all frequencies present in a complex wave.

Frequency modulation—The process of varying the frequency of an rf carrier wave in accordance with the amplitude and frequency of an audio signal.

Ground—A reference value for a voltage or potential; usually the earth or a conductor that is common to other circuits.

Ground wave—That portion of a transmitted radio wave that travels near the surface of the earth.

Interference—Any electrical disturbance from a different source which causes undesirable responses in electronic equipment.

Ionosphere—Highly ionized layers of atmosphere (between the altitudes of approximately 35 and 250 miles) that affect the propagation of radio waves.

Jamming—Deliberate blocking or impairing of radio reception by means of interfering electrical radiation.

Means of signal communication—A medium by which intelligence is conveyed from one person or place to another.

Mega—A prefix meaning one million.

Micro—A prefix indicating one-millionth.

Modulated carrier—An rf carrier whose amplitude or frequency has been varied in accordance with the intelligence to be conveyed.

Modulation—The process of varying the amplitude or the frequency of a carrier wave in accordance with other signals to convey intelligence. The modulating signal may be an audio signal, a video signal (as in television), or electrical pulses or tones.

Network—A designated system, consisting of two or more stations, able to communicate with each other.

Point-to-point circuit—A nonswitched circuit permanently connected between two telephone sets or other terminal equipments.

Radiate—To send out energy into space; as in the case of rf waves.

Radio frequency (rf)—Any frequency of electromagnetic and electrostatic fields capable of energy propagation into space. Radio frequencies are usually higher than those associated with sound waves.

Radio repeater set—Radio set designed to give 2-way service as a receiving and retransmitting unit between two terminals (or a terminal and another radio repeater set).

Radio terminal set—Radio set designed to give 2-way service as a receiving and transmitting terminal (to or with a radio repeater or other terminal). It may contain necessary wide-band modulation or associated carrier multiplexing equipment.

Rear echelon—A rear installation of a headquarters usually consists of those staff agencies having administrative or supply duties that are not located at the main command post (main CP).

Reflection—The turning back of a radio wave from a metallic object, the surface of the earth, or the ionosphere with the angles of incidence and reflection equal and lying in the same plane.

Refraction—A phenomenon which causes a wave that enters another medium obliquely to undergo an abrupt change in velocity in the medium and also in direction. Also, the bending of radio waves in the troposphere or around an object.

Relay—A process of retransmitting intelligence through an intermediate station.

Repeater—A combination of apparatus for the reception and retransmission of signals that are either amplified or reshaped, or both.

Skip distance—The distances on the earth's surface between the points where a radio wave is successively reflected between the earth and the ionosphere.

Simplex operation—A method of operation in which communication between two stations takes place in one direction at a time.

Siting—Properly locate an antenna (or radio set) to obtain optimum performance.

Transmission line—Any conductor or system of conductors used to carry electrical energy from its source to its load.

Tuning—The process of adjusting a radio circuit to resonance with the desired frequency.

Wave length—The distance in meters traveled by a wave during the time interval of one complete cycle. It is equal to the velocity divided by the frequency.

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By Order of *Wilber M. Brucker*, Secretary of the Army:

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USA Sig Tng Cen	11-117, Sig Spt Co

NG: State AG.

USAR: None.

For explanation of abbreviations used, see AR 320-50.